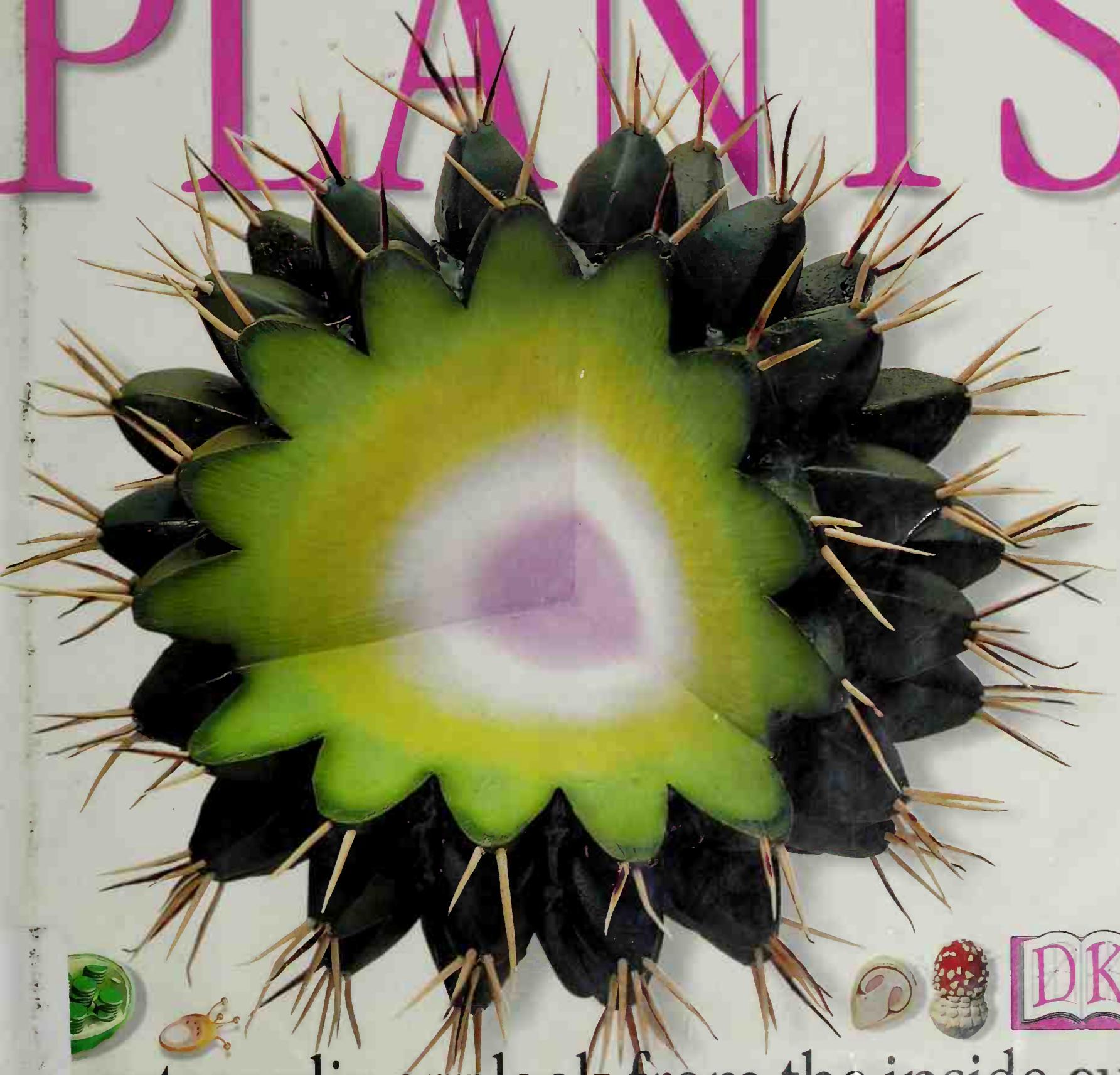


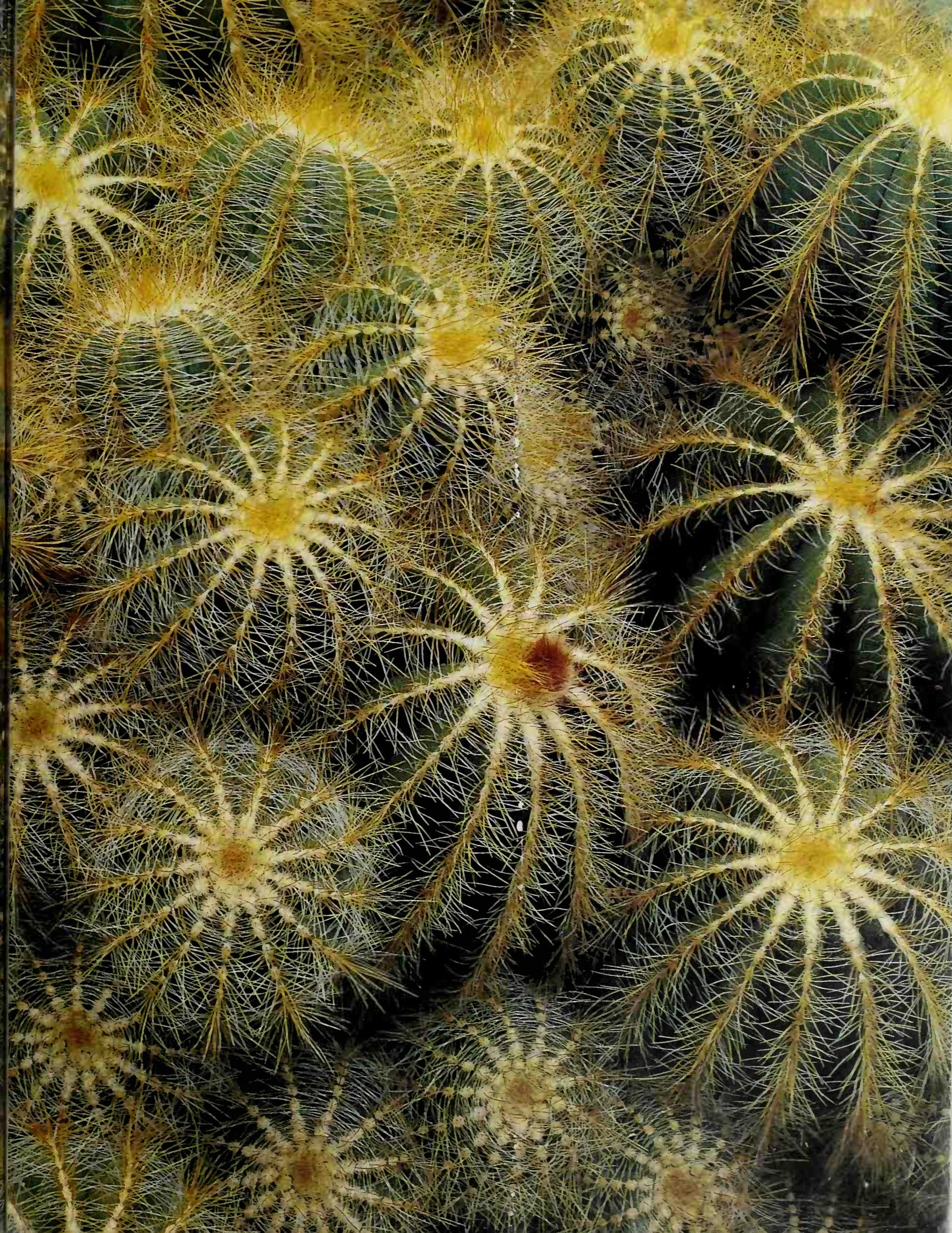
INSIDE GUIDES

INCREDIBLE PLANTS



An extraordinary look from the inside out







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INSIDE GUIDES

INCREDIBLE PLANTS

Written by
BARBARA TAYLOR



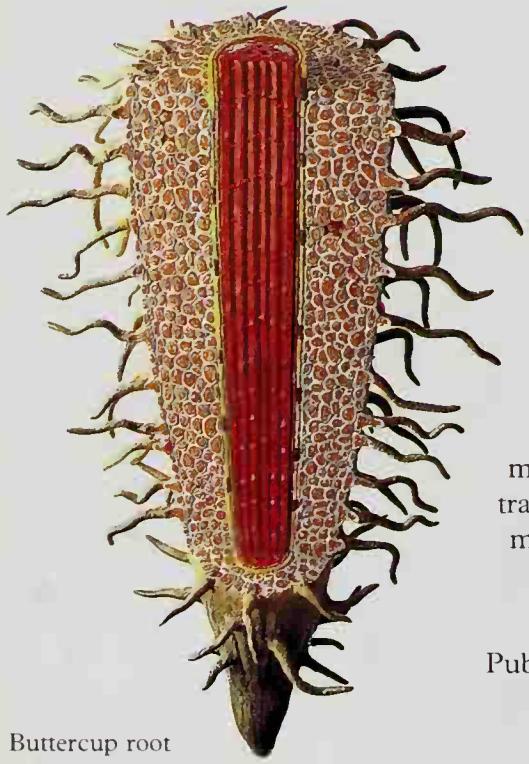


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Pine stem



Buttercup root



Fly agaric
toadstool

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Spore release
in fern



Stages of runner bean germination



Inside a monkshood flower

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Slice through a monkshood flower



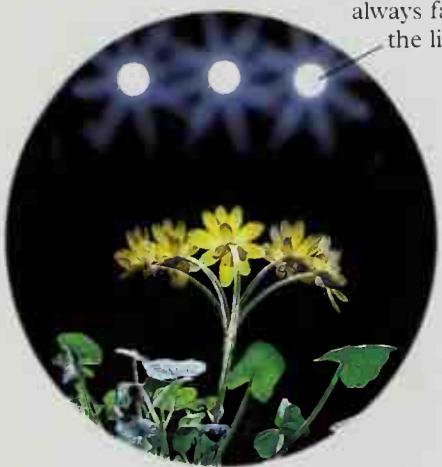
Internal structure of a chloroplast



Plants at work

Without plants, you would not be alive. Most plants can make their own food. Animals, including people, cannot do this. All animals have to eat plants, or eat animals that have eaten plants. Plants do many of the things animals do, such as feeding, breathing, reproducing, and growing.

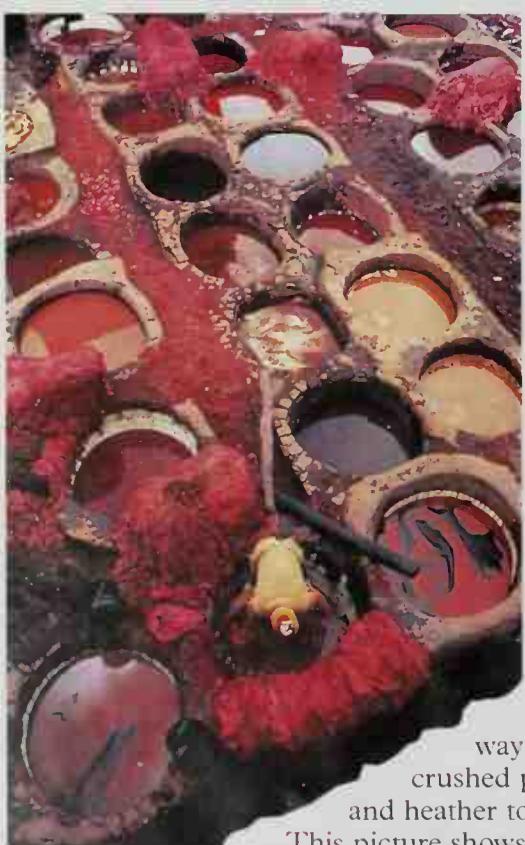
Unlike animals, plants keep growing throughout their lives. Although plants do not move around like animals, they do make small movements, and they use wind, water, or animals to disperse their pollen, seeds, and spores. There are more than 550,000 different kinds of plants in the world.



Sun worshipers

Plants like this lesser celandine can move their flowers to face the sun as it moves across the sky.

They sense the light using pigments in their cells.



This picture shows dye pits in Marakesh, Morocco.

Flowers on the move

Cells send signals that control growth of the flower stalk, so the flower always faces the light.

Building blocks

Plants are made up of microscopic "boxes" of living material called cells. A cell takes in energy and uses this to build itself up and to reproduce. Some plants have only one cell, while more complex plants, such as trees, have many, many billions of cells.

Nucleus

The nucleus is the control center of the cell, rather like the cell's "brain."

Endoplasmic reticulum

This is a mazelike network of membranes that makes and stores chemical substances.

Cell wall

The cell wall is a jacket around the cell made of cellulose layers.

Cell shape

The cell walls are tough, which gives the cell a fixed shape.

Chloroplast

Food is made and stored in chloroplasts (pp. 10–11).

Plant uses

From dyes, food, and medicines to fabrics, perfume, and furniture, people use plants in many different ways. For thousands of years, people have crushed plants such as saffron, lichens, woad, and heather to make dyes for fabrics and leather.

Cytoplasm

The cytoplasm is a jellylike substance that fills the space between the cell membrane and the nucleus.

Plasmodesmata

Threads of cytoplasm called plasmodesmata pass through the cell wall and link one cell to another. Plasmodesmata and cytoplasm are different colors in this model to make the image clearer.

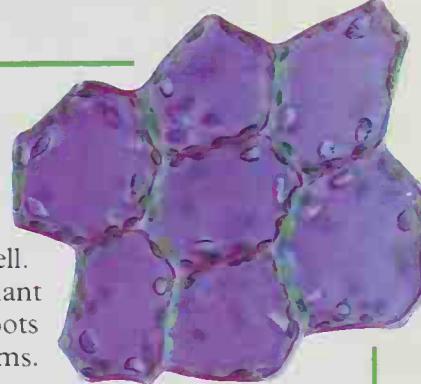
Dictyosome

These gather substances made by the cell as well as making and carrying materials to make the cell wall.

Making food

The chloroplasts, like these in cells of Canadian pond weed, use the sun's energy to make food. Chloroplasts are often found around the edges of a cell.

They occur in nearly all plant cells, except those in roots or inside stems.



Mitochondrion

A mitochondrion breaks down food to release energy for the plant to live and grow.



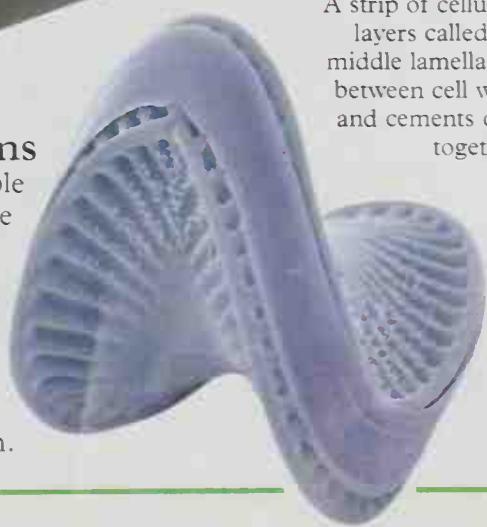
Vacuole

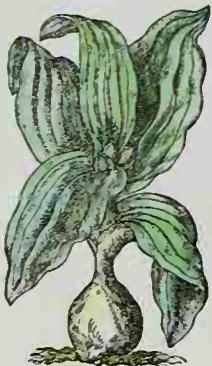
A large sac called a vacuole is filled with cell sap and surrounded by a thin membrane. The vacuole helps the cell keep its shape by pressing against the cell wall.

Diatoms

Some very simple plants look more like spaceships than plants.

Diatoms are microscopic plants made up of one cell surrounded by a hard case with amazing patterns of holes. Each kind of diatom has a different pattern.





Leaf power

Leaves are living factories, making food from water and a gas called carbon dioxide. To fuel their task, leaves use the energy from sunlight, which they capture with a green pigment called chlorophyll. Leaves come in many shapes and sizes, but they are usually thin, flat, and arranged to catch as much light as possible. Some leaves have special features. Furry leaves keep out strong sunlight on mountains. Cactus leaves are narrow spines, stopping the plants from losing too much water in hot, dry places. The thick, waxy leaves of water plants encourage water to run off, preventing the plant from getting waterlogged.



Blood red
Herb Robert was used as a medicine for blood disorders and to heal cuts. Because it is red, the plant was associated with blood.



Spangle gall
Spangle galls form when an oak leaf grows abnormally around wasp eggs laid inside it.

Leaf tenants

Some insects use leaves for the development of their young. Inside each spangle gall on this oak leaf is a tiny wasp grub feeding on the gall tissue. The galls drop from the leaves in fall, and the wasps then develop into adults.



Autumn leaf
In autumn the leaves lose their chlorophyll and turn red all over.



Membrane
An envelope made up of two membranes surrounds and protects the chloroplast.

Granum

Light traps

A plant traps light and makes food inside microscopic disks called chloroplasts, which are inside its leaves. A sectioned chloroplast is shown in the model to the right. It is made up of flat sacs called thylakoids. Chlorophyll in the thylakoids captures light energy and this energy is used to make sugars. Sugars are used by the plant to live and grow, and oxygen is given off as a waste product. The process is called photosynthesis.



Thylakoid

Thylakoids are made from a system of sheetlike membranes arranged neatly on top of each other. Each thylakoid is packed with chlorophyll.



How leaves breathe

A leaf has tiny mouthlike slits called stomata, named after the Greek word for mouths. The stomata are mainly on the underside of the leaf. Gases and water vapor pass in and out through the stomata. A plant uses its stomata to control the rate at which it loses water.

Chlorophyll

Chlorophyll in the thylakoids absorbs blue, red, and violet light energy, and reflects green light, making leaves look green.

Starch grain

Some of the sugars produced in photosynthesis are stored as starch.

Inside and out

Inside leaves, there are veins that carry water and minerals to the leaf and take away food made in the leaf. On the outside, a leaf has a transparent, waterproof layer on both sides.



Leaf structure

The hydrangea's broad leaf and branching vein pattern, seen here on both sides, are typical of a large group of flowering plants called dicotyledons, or dicots. They are called dicots because the seeds first produced by these plants have two seed leaves, unlike monocotyledons, or monocots, which have only one seed leaf.

Stroma
Sugars are made in this dense, granular fluid.

Midrib

The large main vein of the leaf is called the midrib. In this hydrangea leaf, middle-sized veins branch off from the midrib while the rest of the leaf is crisscrossed by minor veins, or veinlets.

Introducing flowers



More than 80 percent of all living green plants have flowers. Flowering plants began to evolve during the days of the dinosaurs. The purpose of a flower is to make seeds that grow into new plants. Although flowers come in an amazing variety of shapes and sizes, they all have a similar plan. A regular flower has four parts joined to the end of a stalk and the parts are arranged in a symmetrical way. All the parts have developed from modified leaves and are arranged in four circles, called whorls. The outer circle consists of sepals, then comes a circle of petals, then one of male parts, and finally female parts. Male and female parts join to make seeds.

Black spot

Glands appear as black dots on the petals. They are characteristic of this flower family.

Yellow petal

Five colorful, wedge-shaped yellow petals attract insect pollinators.



Umbrellas

Flowers in the carrot family, like this hogweed, are grouped together at the same level in umbrella shapes called umbels. This arrangement makes the small flowers more obvious to passing insects and provides the insects with a landing platform. Insects carry pollen from flower to flower (pp. 16–17).

Flower structure
These tulips have six petals. They are monocots (pp. 10–11), as are grasses, palms, and orchids. Monocot flowers have parts usually divided into threes or multiples of three. Dicots, such as trees and roses, have flower parts that usually divide into fours or fives.

Saucer-shaped
This model shows the parts of a regular flower called St. John's wort. The flower is shaped like a saucer, making it easy to see the rings of modified leaves. Years ago, this flower was thought to ward off evil spirits. Today it is used to treat depression.







Flower shapes

Flower parts can be arranged in all sorts of ways, and flowers of different families have different shapes. Regular flowers can be divided into two equal halves by any line drawn through the center of the flower.

The petals are usually of a similar shape, an equal distance apart, and grow out from the middle of the flower. Irregular flowers can only be divided into two equal halves one way. The two halves are usually mirror images of each other. Irregular flowers are usually of a complex shape. The different parts are not an equal distance apart, and may vary in number or size. For instance, some petals may be larger than others, or be joined to form hoods or tubes. Some parts may even be missing.



Wolf pea

The name of this flower, lupine, comes from the Latin word for wolf. The lupine also belongs to the pea family. A pea flower has both male and female parts. They are hidden inside two boat-shaped petals called the keel, like the keel of a boat. Above the keel are two more petals called wings, and above the wings is one large, colorful petal called the standard.

Green tree frog

The green tree frog of America is in a good position to catch passing insects attracted by the bright colors of the lupine.

In a spiral

Lupine flowers are arranged in a spiral around the flower stalk.

Tall spike

Monkshood flowers grow in a tall spike above the leaves, with many flowers on each spike.



Trumpet flowers

The shapes of complex flowers are often linked to the animals that spread their pollen. Many bright-red tube-shaped flowers, like this fuchsia, are pollinated (pp. 16–17) by hummingbirds. Red is attractive to the birds.

Old stamen

Old stamens bend back. Their pollen has already been released.

New stamen

New stamens bend down. They are not ready to release pollen.

Stigma

Female stigmas in the center of the flower receive pollen from another monkshood.

Ovary

The ovary is right in the middle of the flower, where it is well protected.

Inside out

A closer look inside a monkshood flower reveals the male and female parts and a large nectary standing up above them. The young stamens are bent down. Once the stamens have released their pollen, they bend back.

Nectary

Two large nectaries contain sweet nectar to "reward" the bees for carrying pollen from flower to flower. When the bees reach for the nectar, they are likely to brush against the pollen sacs.

Stamen

Bumblebees carry this pollen to other monkshood flowers so that seeds can develop.

Upper sepal

The upper sepal forms a hood above the male and female parts of the flower.

Stigma

Female stigmas are on the end of a stalk or style. Pollen must land on the stigmas to reach the ovary. The stigmas are like a doorway to the ovary.

Helmet flower

Monkshood belongs to the buttercup family, which has many members with a simple flower structure.

Monkshood, however, has irregular flowers that are not symmetric. The colored parts of the flower are sepals, not

petals. The top sepal is a large, helmet-shaped hood

that is upright. Inside the hood are two large nectaries.

Bumblebees land on the lower sepals and climb up to the nectaries, becoming dusted with pollen on the way.

Lower sepal

Lower sepals form a landing platform for bees.

Animal pollination

Insects and other animals are attracted by the bright colors and scents of many flowers. They feed on the pollen and on a sugary food made by the flowers called nectar. During their visit, the animals may accidentally pick up some pollen on their bodies. If the animals then visit another flower of the same kind, the pollen may rub off onto the stigma. The transfer of pollen from anther to stigma is called pollination. Pollination leads to the development of seeds.

If flowers swap their pollen, the new plants that grow from the seeds are likely to be strong, healthy, and stand a good chance of survival.



Pollen exchange
As the bee climbs inside the flower to feed on the nectar, it brushes against the anthers and stigma, collecting and delivering pollen.

Heavyweight

Common toadflax flowers are pollinated by bumblebees, which are strong and heavy enough to push open the "mouth" of the flower. They also have long tongues to reach the nectar found at the end of a long, pointed spur.



4 The bee flies off with the bucket orchid's pollen stuck to his back. If he falls into the bucket of another orchid of the same species, the pollen on his back may be brushed off onto the stigma as he struggles to escape from the watery trap.

Bucket orchid

The shapes and colors of orchid flowers are designed to make sure that a particular kind of insect collects and delivers pollen during its visit. The male bees that pollinate bucket orchids are enticed to the flowers by a perfume that they take from the petals and use to attract female bees in courtship.

Watery liquid
Two small knobs produce a watery liquid that drips into the bucket.

Pocket

The bees take perfume from the petal and store it in pockets on their back legs.

1 When a bucket orchid flower opens, liquid drips down into the bucket. It collects to form a pool. The flower then gives off a strong smell. The perfume attracts male euglossine bees, which scrape off droplets of the oily, liquid perfume with their front feet.

2 While collecting perfume, a male bee sometimes slips and falls down into the bucket. He swims around in the liquid, but cannot climb up the sides of the bucket or fly out. Eventually, he discovers the only escape route, a narrow opening in the front wall of the bucket.

**Bat couriers**

This long-nosed bat has a long tongue with a brushlike surface to scoop up lots of nectar and pollen. Some pollen catches on the bat's head, or the front of its body, and is carried from flower to flower as it feeds.

Furry feeders

As the Australian pygmy opossum laps up the nectar from Banksia flowers, its soft fur becomes dusted with pollen. These small mammals are good at climbing to reach the flowers, but are more clumsy than insects and often damage the flowers.



Pollen journeys

Many flowering plants in cold, wet, and windy climates, where there are few insects, use the wind to carry their pollen. Wind-pollinated plants, such as trees and grasses, often grow together in large numbers to increase the chances of their pollen blowing from anthers to stigmas. A few plants, such as pondweeds and sea grasses, rely on water to move their pollen. Pollination by wind or water is a much more haphazard process than pollination by insects or other animals.



Wind pollination

Clouds of pollen from wind-pollinated plants, such as this sedge, are one of the main causes of hay fever. The plants release huge numbers of pollen grains. Their flowers are usually small with drab colors since they do not need to attract insects. Anthers and stigmas hang outside the flower to increase the chances of pollen being blown away, and of pollen from elsewhere landing.





1 Ribbon weed is pollinated at the surface of the water. It has separate male and female plants. The tiny male flowers form inside a leaf-like envelope called a spathe near the bottom of the plant. Each flower has two stamens wrapped up inside three sepals.

water currents.

Unopened male flowers inside leaflike envelope

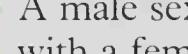
7 The pollinated flower is pulled down to the bottom of the plant, where it ripens into a fruit, protected by the leaves.

Field elm pollen grain

Pollen packages
Pollen carried by the wind is as small and light as possible so that it can travel long distances. The grains often have a smooth surface since they do not need to stick onto animals. A smooth pollen grain flies faster through the air.

From pollen to seed





When pollen lands on the stigma (pp. 12–13) of a flowering plant, it is only the first step toward making a seed. A pollen tube grows out of a pollen grain, into the stigma, down the style, and into the ovary. A male sex cell travels down the pollen tube and fuses with a female sex cell stored in the ovary, creating a seed.

This fusion is called fertilization. After fertilization, a baby plant starts to develop inside the seed. The ovary gets bigger and turns into the fruit, which contains and

Petals

Petals
Poppy flowers have four crumpled, overlapping petals, which soon fall.

Annual flowers

Annual flower
Some plants, such as poppies, make seeds once and then die.

They are called annuals and they survive until the next year as seeds buried in the soil. Each poppy flower can produce hundreds of seeds.

protects the seeds. Once ripe, the seeds are released by the plant or are spread by the wind, water, or animals.



Animal dispersal

Fleshy fruits may be brightly colored or have a shiny surface to attract animals such as this waxwing.

Animals and birds drop the seeds, or pass the seeds out in their droppings. This moves the seeds away from the parent plant, where they are more likely to survive.



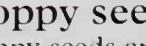
Poppy ovary

Inside this poppy ovary are the ovules waiting to be fertilized. The ovary has between eight and ten sections, or compartments.

Shaking seeds

When the fertilized seeds are ripe, the ovary forms a dry, hollow fruit with holes around the rim. As the wind blows, the ripe seeds are shaken out through the holes, like pepper out of a pepper shaker.

Poppy seeds



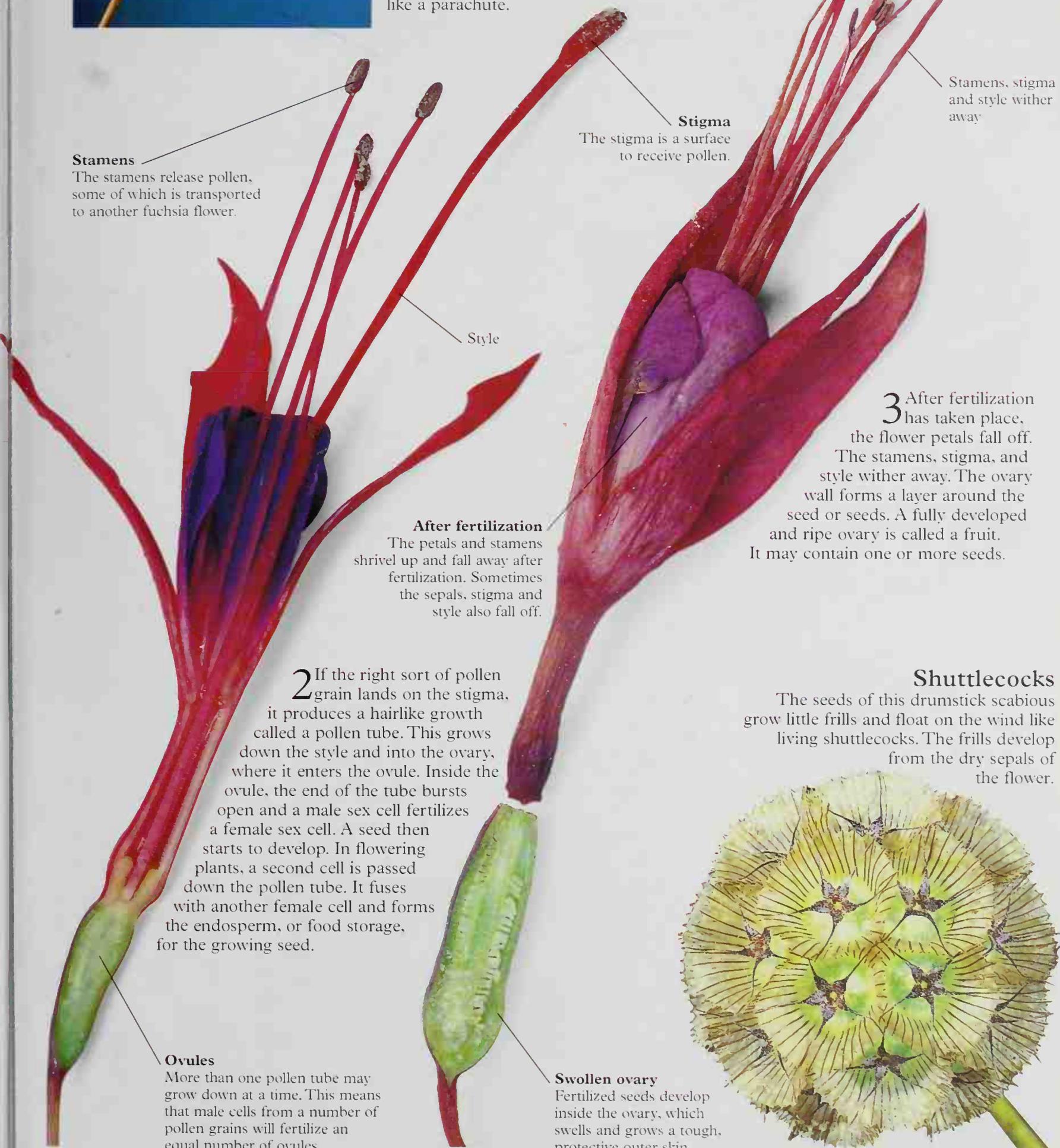
Poppy seeds
Poppy seeds are small and light, so they float easily on the wind. They usually travel only short distances, perhaps a few feet or so. They are blown farther in a strong wind.

1 Before a fuchsia flower opens, the ovary is packed with rows of white ovules. These ovules contain the eggs, one in each. Each ovule may develop into a seed if it is fertilized by a male sex cell from a pollen grain.



Parachutes

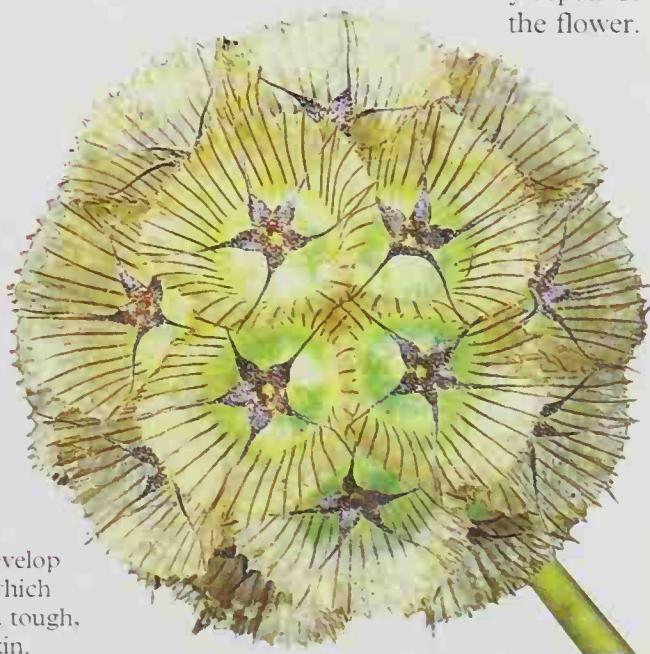
Some seeds have wings, vanes, and even parachutes to help them catch passing air currents and float long distances on the wind. Each dandelion seed has a mass of hairs called a pappus that works like a parachute.



3 After fertilization has taken place, the flower petals fall off. The stamens, stigma, and style wither away. The ovary wall forms a layer around the seed or seeds. A fully developed and ripe ovary is called a fruit. It may contain one or more seeds.

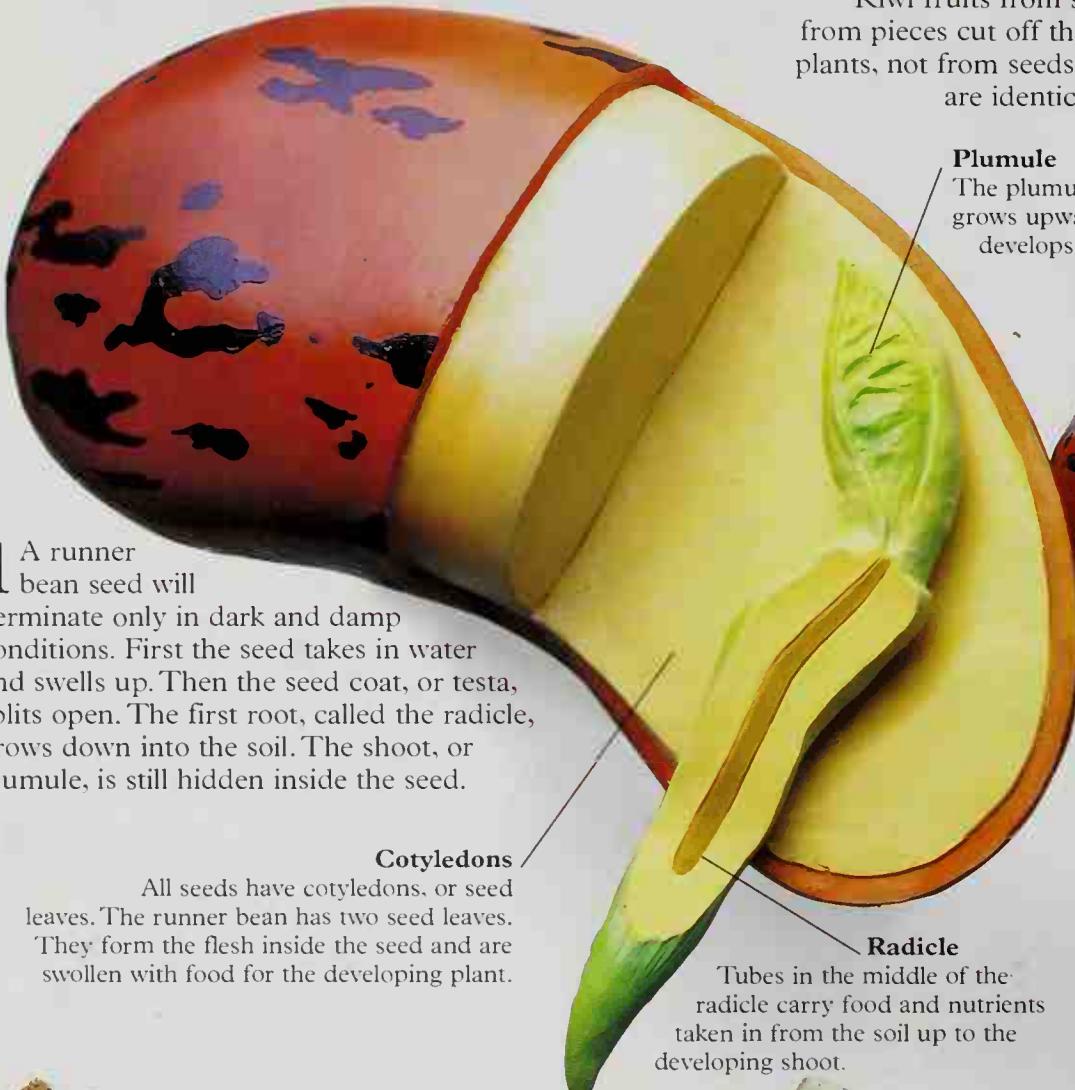
Shuttlecocks

The seeds of this drumstick scabious grow little frills and float on the wind like living shuttlecocks. The frills develop from the dry sepals of the flower.



Plant beginnings

A flowering plant is born when its seed comes to life in a process called germination. Before this happens, a seed may remain dormant for weeks, months, or even years. In order to germinate, a seed needs moisture, oxygen, and the right temperature. Some seeds need a trigger to start germination, such as fire, or passage through an animal's gut.



1 A runner bean seed will germinate only in dark and damp conditions. First the seed takes in water and swells up. Then the seed coat, or testa, splits open. The first root, called the radicle, grows down into the soil. The shoot, or plumule, is still hidden inside the seed.

Cotyledons

All seeds have cotyledons, or seed leaves. The runner bean has two seed leaves. They form the flesh inside the seed and are swollen with food for the developing plant.

Kiwi fruits from stores are grown from pieces cut off the stem of parent plants, not from seeds. New kiwi plants are identical to their parents.

Plumule

The plumule, joined to the radicle, grows upward and eventually develops into the first shoot.

2 The plumule breaks through the seed coat and starts to grow upward, toward the light. At first it is bent in a hook shape so that the leaves are drawn up through the soil backward. This protects the delicate growing tip and the fragile leaves.



Lychee

The lychee has a fleshy jacket called an aril around the seed. As animals eat the aril, the seed inside drops to the ground, where it begins to germinate.

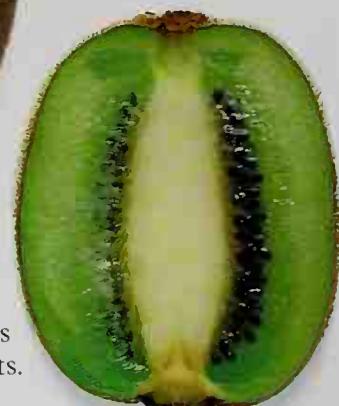


Rice seedlings

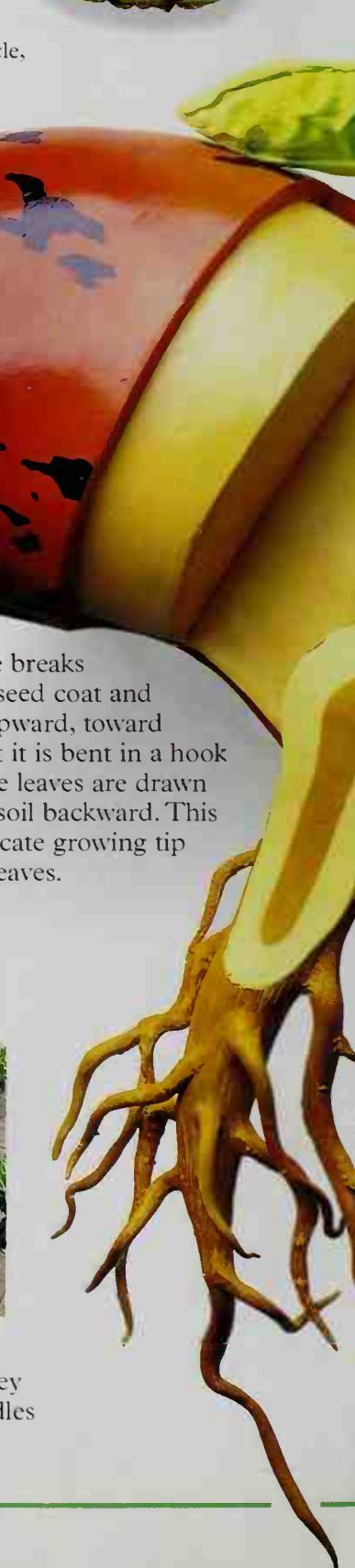
Rice seedlings have to be grown in water. When they are big enough, the seedlings are gathered into bundles to be planted out in flooded paddy fields.



Chinese gooseberry
The kiwi fruit is also called the Chinese gooseberry. The fruits grow on vines in the forests of China.



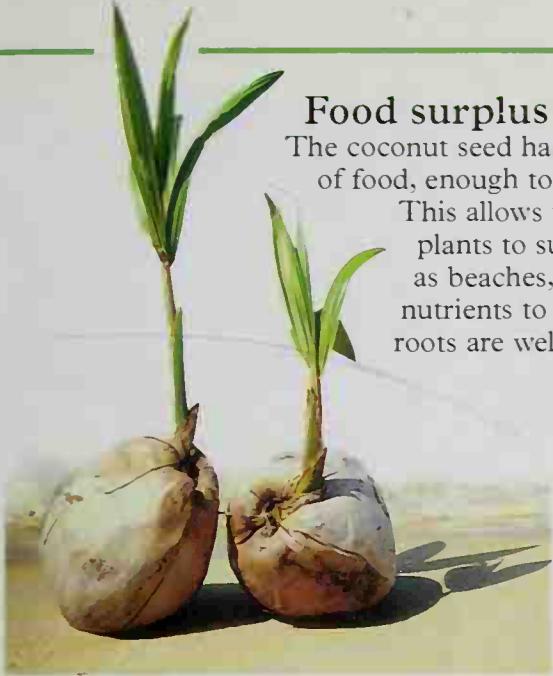
Kiwi



Food surplus

The coconut seed has a massive store of food, enough to last for a year.

This allows the young coconut plants to survive in places such as beaches, where there are few nutrients to be found until the roots are well developed.



True leaves

The first true leaves are folded up so they will slide through the soil more easily.

Plumule curved into hook shape

Open air

The shoot has come up through the earth's surface into the air.

Tough seed coat

The tough seed coat protects the embryo and its food store until germination happens.

Once above the soil, the plumule straightens out, lifting the first true leaves clear of the soil surface. The leaves open out and start to make food by the process of photosynthesis (pp. 10–11). This food provides energy for growth.

Root system

The root system branches out to anchor the plant in the soil and take in more water and nutrients for the growing shoot.



4 The stem grows taller and stronger, holding the leaves up in the air to catch the sun. Runner bean plants climb over other plants and produce their own flowers about six weeks after germination. The seeds that develop from the flowers after fertilization produce new plants and complete the life cycle.

Shrivel up

The seed case is not needed now and starts to shrivel up and disintegrate.



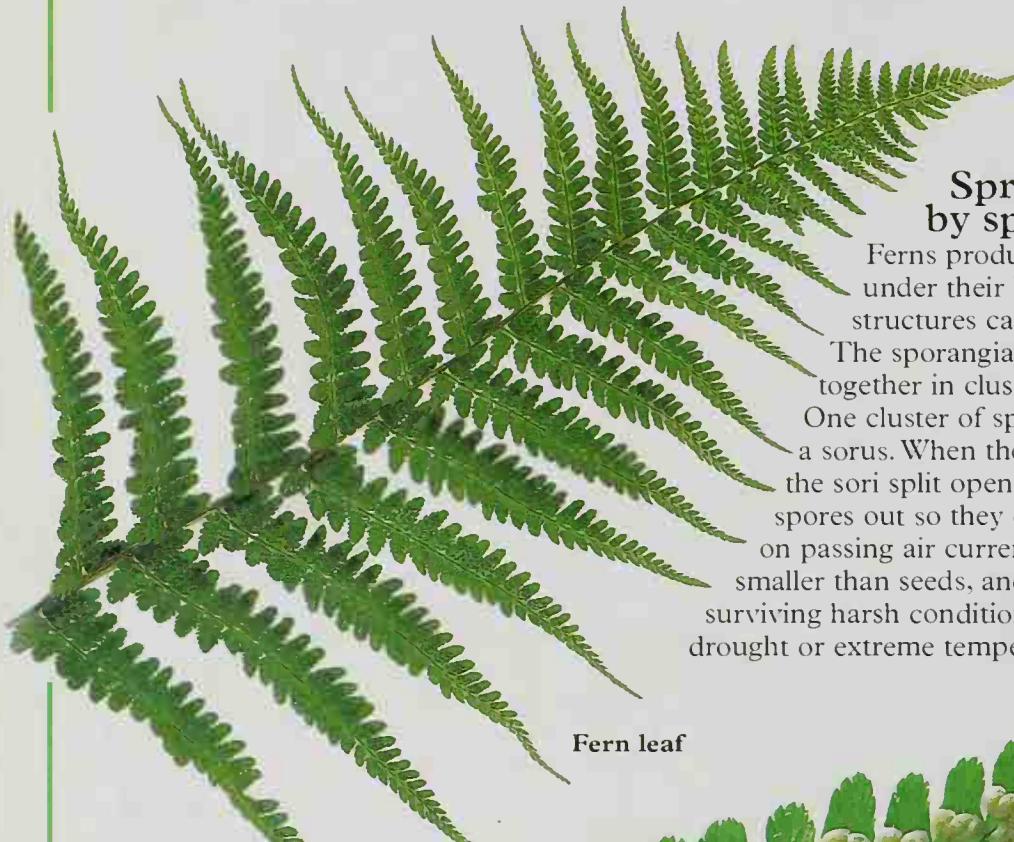
No more nutrients

As the nutrients in the seed leaves are used up, they will shrivel and wither.

This model is not to scale.

Plants without flowers

Some plants do not have flowers or produce seeds. Plants such as ferns, mosses, liverworts, and horsetails are spread by means of small, simple structures called spores. But these plants also exist in two different forms during one life cycle. One form produces spores, the other form produces eggs and sperm. For instance, the leafy fern plant produces spores. But each spore grows into a tiny, heart-shaped prothallus, which produces eggs and sperm. A sperm has to swim through water to join an egg before a new fern plant can develop.



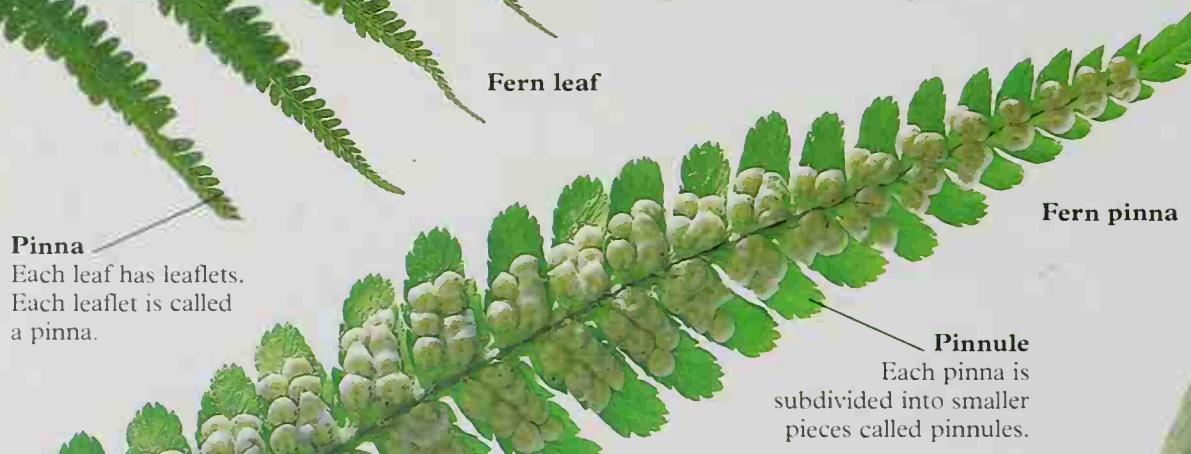
Fern leaf

Pinna
Each leaf has leaflets.
Each leaflet is called
a pinna.

Spreading by spores
Ferns produce spores under their leaves in structures called sporangia. The sporangia are grouped together in clusters called sori. One cluster of sporangia is called a sorus. When the spores are ripe, the sori split open, flinging the spores out so they can drift away on passing air currents. Spores are smaller than seeds, and are good at surviving harsh conditions, such as drought or extreme temperatures.

Sori
There are six sori
underneath this
pinnule.

Fern pinnule



Fern pinna

Pinnule
Each pinna is
subdivided into smaller
pieces called pinnules.



Indusium

The indusium grows out from the surface of the leaf to cover the clusters of spores.

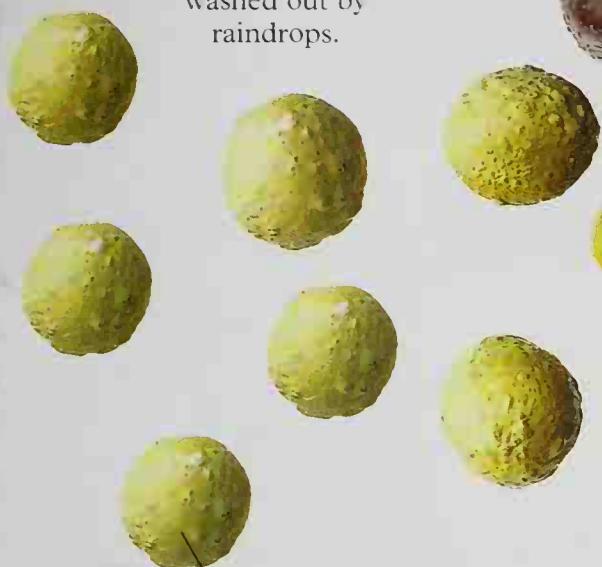
Spore holder
Each sporangium
contains 48 or 64
dark brown spores.

Surprise packages
Each sorus is surrounded by a thin flap called the indusium. As the sorus ripens, the indusium changes color from green to brown. Eventually it withers, revealing the sporangia underneath.



Spore caps

In addition to reproducing from spores, liverworts can produce new plants from small groups of cells called gemmae. These develop inside gemmae cups and are washed out by raindrops.



Safety in numbers

A large fern may produce several hundred million spores in a year, but only a few of these will develop into new fern plants.

Fern sorus

Spore catapult

A sporangium catapults spores out into the air. A strip of special cells along one side dries out, and the top of the capsule, containing the spores, bends gradually backward. Eventually, the top springs forward again, suddenly hurling the spores out.

Inside view

Peeling away the protective indusium reveals clusters of delicate sporangia, microscopic balls of spores on stalks. The stalks are attached to a slight thickening of the leaf surface called the placenta.

Thin wall

The wall of the sporangium is only one cell thick.

Fern sporangium



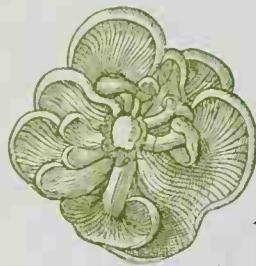
Annulus

A row of cells called the annulus along the back of the sporangium dries out. This causes it to bend back.

Stalk

This stalk is attached to the pinnule at the placenta.



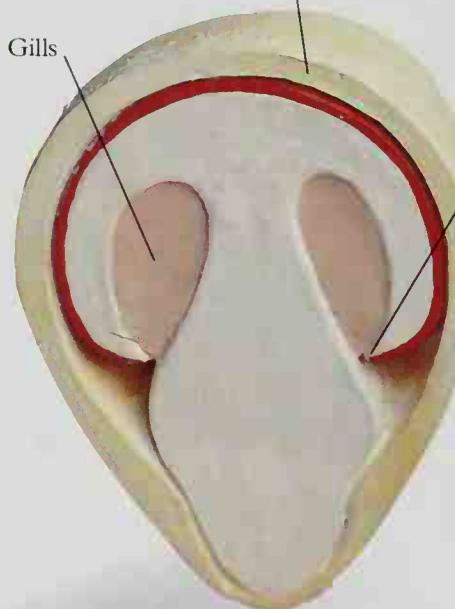


Fungal spores

A fungus is more complicated than it first appears. Mushrooms or toadstools are the visible parts of fungi and hold spores, which may grow into new fungi. The rest of a fungus is hidden in the ground or the organic matter in which it grows. It is made up of a maze of branching threads called hyphae that are woven into a mat called a mycelium. A fungus has no roots, stems or leaves. Fungi cannot make their own food. Some feed on dead matter, others attack living animals and plants.

Universal veil

An outer, protective veil forms a membrane around the developing toadstool.



Sticky veil

An inner veil joins the cap to the stalk and covers the gills.



1 When a fly agaric toadstool reproduces, the underground hyphae join together to form a button-shaped toadstool enclosed in a protective veil. The cap of the toadstool is joined to the stalk by another, inner, veil.

2 As the cap expands, the universal veil splits and the cap emerges into the light. It is still rounded at this stage. Little white pieces, which are the remains of the veil, cover the cap.



Spore explosions

Pilobolus fungi produce spores in structures called sporangia that form on the end of stalks. Pressure builds up in the stalk until eventually the whole sporangium shoots off into the air. It travels for several feet. Pilobolus means "hat thrower."



Annulus

The remains of the inner veil form a ring called the annulus around the stem.

Volva, remains of the universal veil



Gills
Spores are shed from vertical plates called gills that hang under the cap.



Trumpet
Bracket fungi, such as this trumpet oyster mushroom, have gills running down a short stem to one side of the cap. The spores are lilac colored.



Fire balls
Puffballs are bags that eject spores out of a hole in their tops, like a cloud of smoke. The wind carries the spores to new places. One giant puffball may produce as many as 7 million million spores.

Dried up
The pieces of the universal veil dry around the edges first, causing them to curl upward.



3 The fly agaric's stalk grows taller. The cap opens out into an umbrella shape and the gills hang vertically under the cap so mature spores can be dispersed. The inner veil forms a ring around the stem called the annulus.

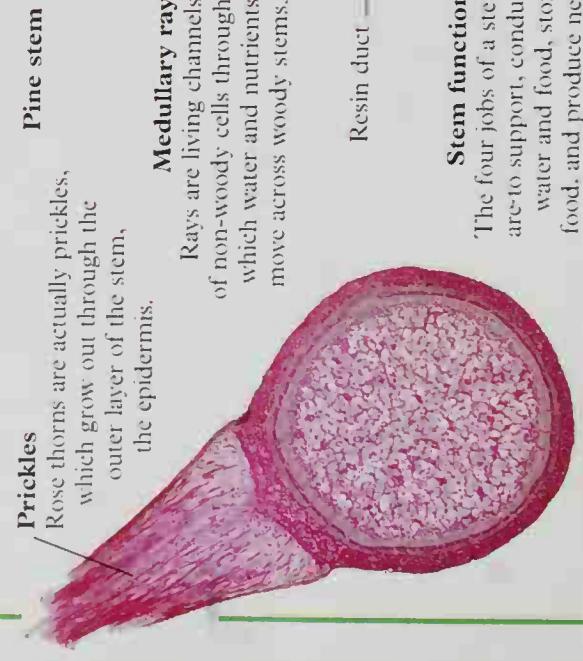
4 The gills carry spores at all stages of development. The spores form on the tips of club-shaped structures called basidia, which are located on the edge of the gills. One toadstool may discharge as many as a million spores a minute for several days. The drier the wind is, the farther the spores will be carried.

Roots and stems



Roots grow downward in search of water and mineral salts found in the soil. They anchor the plant in place. Stems are above the ground. They hold the leaves up and out, toward the light. They also hold flowers in positions where wind, water, or animals can pollinate them.

In shrubs and trees, the stems are woody for extra support. Smaller plants with non-woody stems rely on the pressure of the watery sap in their stems for support. Both stems and roots contain pipes through which food and water move.



Thorny skin

Non-woody stems, such as the young stems of roses, have a thick, waterproof "skin." The middle of the stem is made up of pith.

Pathways and pipes

In a stem, the pipes that carry water and food are usually around the outside, where they make the stem strong but also allow it to bend in the wind. The water pipes, called xylem, are made of dead cells with thick walls. The food pipes, called phloem, are made of living cells with thin walls.

Pith
Large, soft-walled cells in the middle of the stem make up the pith.

Resin duct
Resin ducts are long, hollow tubes that produce sticky resin on their inner walls.

Prickles
Rose thorns are actually prickles, which grow out through the outer layer of the stem, the epidermis.

Pine stem
Medullary ray
Rays are living channels of non-woody cells through which water and nutrients move across woody stems.

Stem functions
The four jobs of a stem are to support, conduct water and food, store food, and produce new living tissue.

Xylem

Bark
Bark forms a protective outer "skin" for woody plants. It is made of corky cells.

Celery

The stringy bits in a celery stalk are the water pipes. They pass water from the soil to the leaves growing above the soil surface.



New stems for old
The trunk of this tree has been cut a little way above the ground (pollarding) to encourage lots of thin, woody stems to grow for use by people.

Cambium layer
Cells in the cambium layer divide to produce more xylem and phloem cells.

Rings of xylem

'The wood of trees, such as this pine, is mostly made up of rings of xylem cells.

Bark

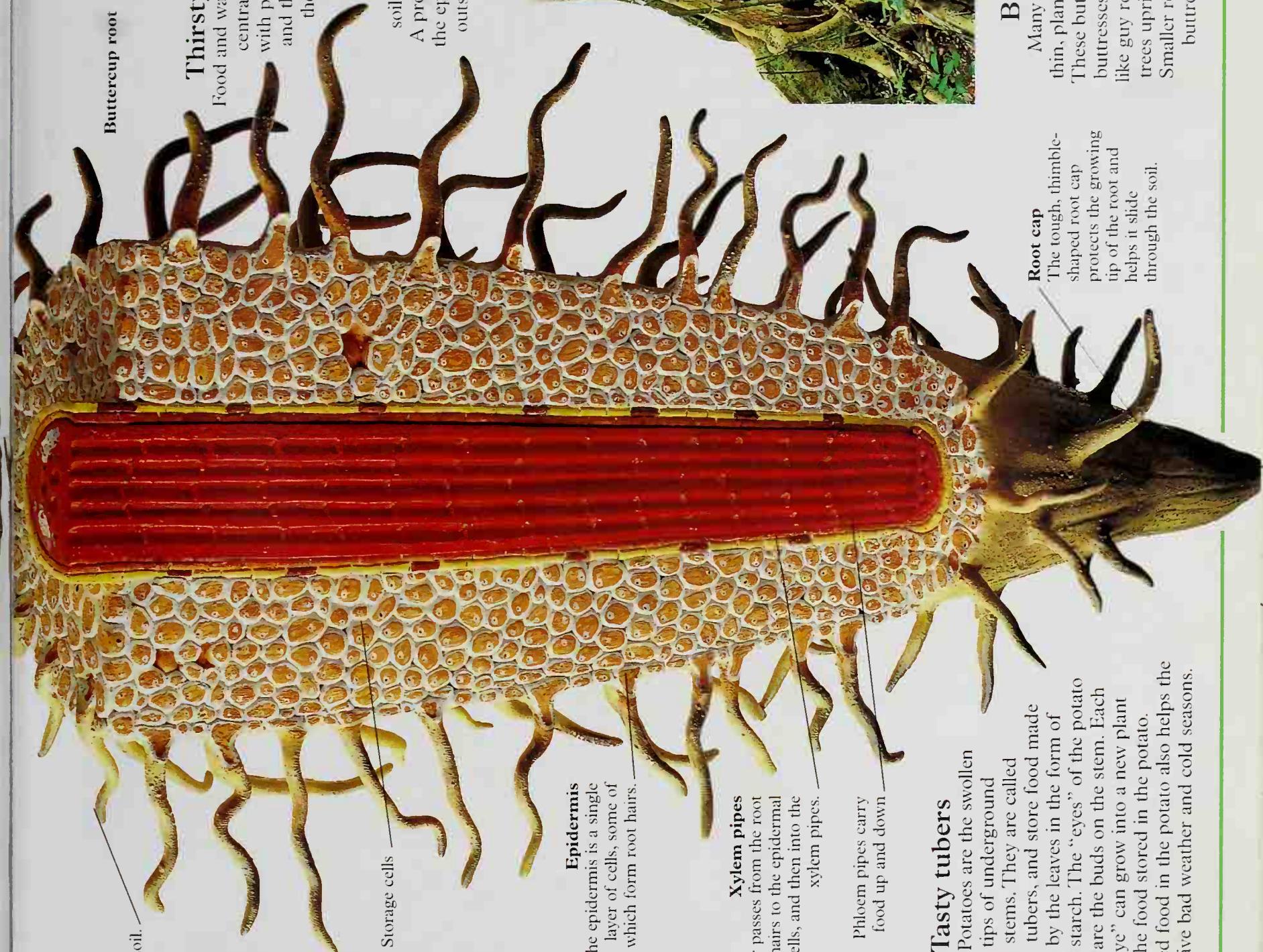
Root hairs

The mass of root hairs increases the surface area of the root so that it can absorb water and minerals from the soil.



Thirsty roots

Buttercup root
Food and water pipes form the central core of a root together with packing and storage cells and the water-filled spaces around them. This arrangement makes the root tough in the middle so that it can bend and twist its way through the soil without being squashed. A protective layer of cells called the epidermis covers the outside of the root.



Plant props

Mangroves grow a tangle of prop roots sticking out from the stem. They help prop up the plant in swamps. They also trap mud, building up the swamp level.

Epidermis

The epidermis is a single layer of cells, some of which form root hairs.

Xylem pipes

Water passes from the root hairs to the epidermal cells, and then into the xylem pipes.

Phloem pipes

Phloem pipes carry food up and down

Tasty tubers

Potatoes are the swollen tips of underground stems. They are called tubers, and store food made by the leaves in the form of starch. The "eyes" of the potato are the buds on the stem. Each "eye" can grow into a new plant using the food stored in the potato.

The stored food in the potato also helps the plant survive bad weather and cold seasons.



Buttress roots

Many tropical trees produce thin, planklike roots above the soil. These buttress roots look like flying buttresses on a cathedral. They act like guy ropes on a tent, pulling the trees upright in thin, tropical soils. Smaller roots grow down from the buttress roots into the soil.

Root cap

The tough, thimble-shaped root cap protects the growing tip of the root and helps it slide through the soil.

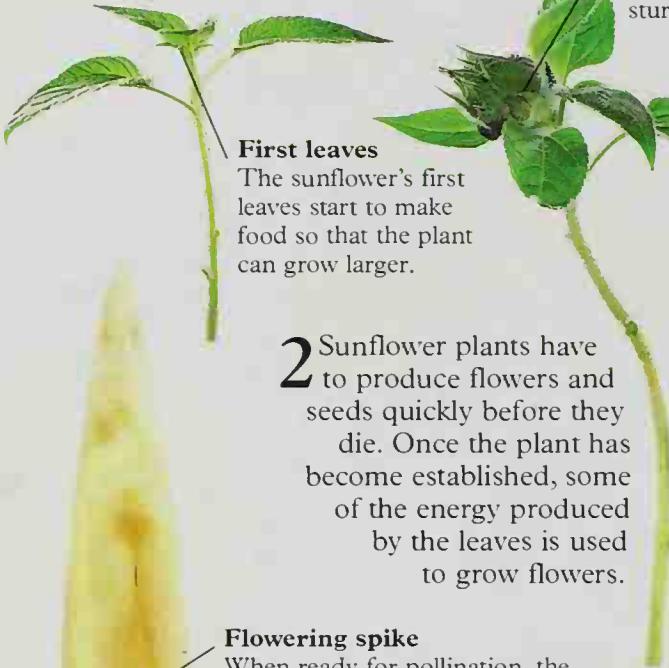


Amazing growth

Plants grow bigger when their cells divide and expand. Some parts of a plant, such as leaves, flowers, and fruits, usually grow to a fixed size. Other parts, such as roots and stems, may keep growing throughout the life of the plant.

Plant growth is slow but powerful. Most plants grow about 0.39 in (1 cm) a day, but the force of the growth is such that some plants can push their way through concrete, bricks, and asphalt. Plants have different life spans. Some live for one or two years only and grow mainly in length, while others live for many years and grow thicker as well as longer.

1 Sunflowers are annual plants that complete their life cycle in one growing season. They grow from seeds and send up seed leaves above the ground. These leaves grow larger and make food for the growing plant until the true leaves take over.



2 Sunflower plants have to produce flowers and seeds quickly before they die. Once the plant has become established, some of the energy produced by the leaves is used to grow flowers.

Flowering spike
When ready for pollination, the flowering spike heats up and gives off a horrible smell, like rotting meat. This helps attract bees for pollination.

Spatha
The huge flowering spike, or spadix, is surrounded by a bell-shaped spathe up to 9.8 ft (3 m) across.

Fast flower

The unusual flowering structure of the titan arum grows at great speed, pushing upward at about 3.9 in (10 cm) a day. The flower, which is found in Sumatra, eventually grows 9.8 ft (3 m) tall, and yet opens for only two days. Each plant probably flowers about three times in its 20-year life span.

Flower bud

The bracts around the bud peel back to reveal the flowers inside. The "petals," which are actually individual flowers, are still tightly closed at this stage.

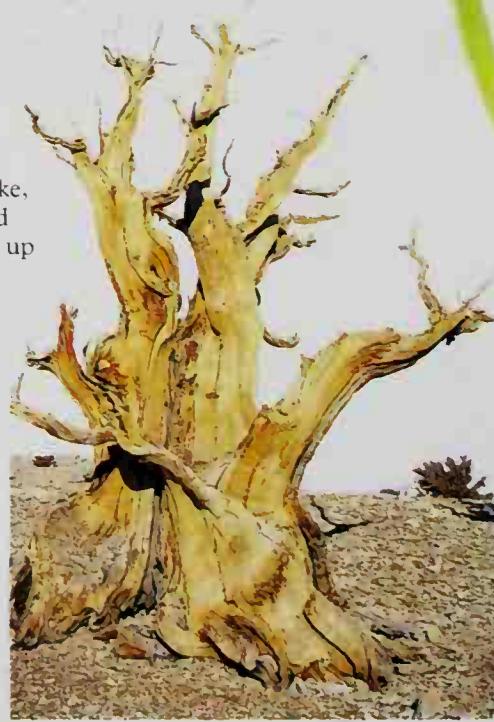
Bracts

At first, the buds are protected by sturdy bracts.

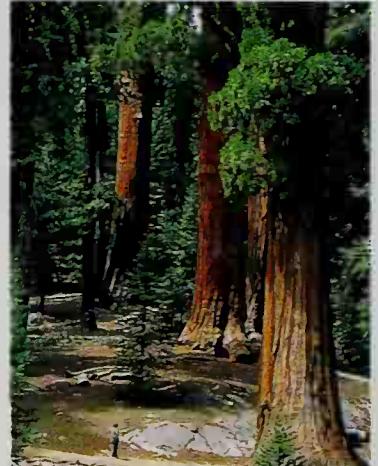


Record breaker
The biggest living thing in the world is one of the giant sequoia trees in California. It is called the General Sherman and is 289 ft (88 m) high, with a trunk 79 ft (24 m) wide. The wood in the tree would make 5 billion matches.

3 The sunflower stem grows in length, with most of the growth being concentrated in the growing tips of the roots and shoots. These tips are called meristems, and it is here that the cells keep dividing and increasing in number. Unlike animals, plants can also grow by making existing cells bigger.



Old age plants
The oldest living things in the world are plants. Bristlecone pine trees in the mountains of California are more than 4,600 years old. They were alive when the ancient Egyptians were building the great pyramids at Giza.



Bulb growth

Daffodils grow from bulbs, which are made up of swollen leaf bases

wrapped around a short, underground stem. A new bulb grows out from the side of an old one. The new bulb can be separated from the old one to make a new plant.



"Petals"

The "petals" are still crumpled up and folded, but will open out to form disk-shaped flowers.

4 The flower begins to open. Its bright yellow "petals" and the nectar it produces attract various insects for pollination. Many growers place honeybee hives in their fields of sunflowers to encourage the bees to pollinate the flowers.

Flower head

Each of the small flowers, or florets, around the edges of the flower head has just one yellow petal.

Cultivation

The cultivated sunflowers grown as crops were developed from the wild sunflowers of Central America.

The wild flowers are small, with only a few seeds, and the plants have flimsy stems.



Stem support

The stem supports the leaves and flowers and stops the plant from toppling over.

Stem

Sunflower stems are very strong, which is unusual for an annual plant.

5 Sun trap
The leaves open out flat and spread wide to catch the sun.



Growing noises

It is sometimes possible to hear plants growing. Bamboo shoots may make squeaking and creaking noises as they push their way through the protective layers around the base of the shoot.

5 Sunflowers can grow up to 13 ft (4 m) tall, and probably have the tallest stems of any annual plant. After pollination, seeds develop that contain food stored as oil. Growers crush the seeds to remove oil.

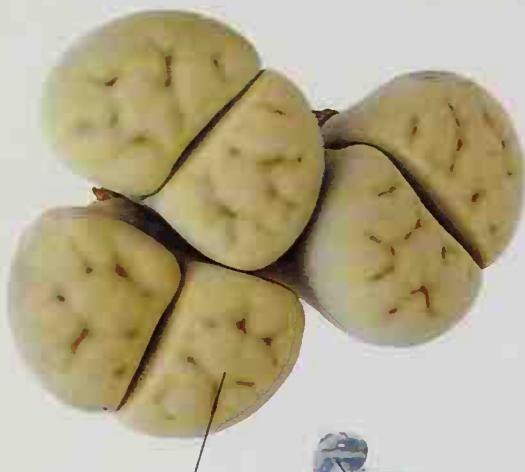
Plant defense



Plants have to be very tough in order to survive. They are rooted to the spot, unable to escape the animals that eat them, so they are often protected by armor, weapons, poisons, or disguises. Many plants have spines, thorns, or stings; others rely on poisonous chemicals. Living stones are camouflaged to look like stones to deter animal and insect attackers, while mimosa plants have extra-sensitive leaves that can move around to shake off insects. Generally, plants are able to recover from an attack more successfully than most animals because they can grow new parts to replace damaged ones.

Matching patterns

Mottled patterns on the leaves match those on the stones around them.



Drops of poison remaining on tip of sting

Broken tip

The tip of the sting has broken off. The remaining point is sharp enough to make a hole in an animal's skin.

Clever camouflage

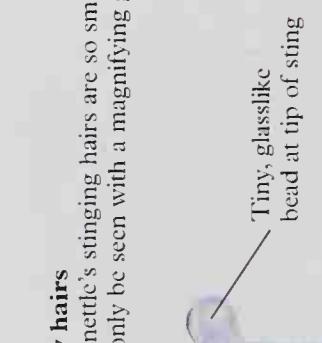
Living stones are aptly named. Their leaves are camouflaged to look like the stones they live among in the desert. Swollen leaves store water, which animals need to drink, yet the plants merge into the desert and are hard to see. Because of its ingenious camouflage, the living stone often escapes being eaten.

Tiny hairs
The nettle's stinging hairs are so small they can only be seen with a magnifying glass.



Sting top

The stinging hair tapers near the top, where the walls are thicker and stiffened with silica.



1 The nettle's stinging hair is an elongated single cell (pp. 8–9). The cell has glasslike walls and contains an irritating liquid. It has a broad, rounded base, but tapers gradually to a delicate point with a beadlike tip. When an animal is stung, the poisonous sap inside the sting produces a burning, stinging feeling and a rash.

Stinging hairs

Poisonous, needlelike stinging hairs grow out from the surface of nettles' stems and leaves. Although stings protect the nettle against larger animals, they are no defense against smaller creatures, such as butterfly caterpillars, which simply eat their way around the stings.

2 When an animal brushes against a stinging hair, the brittle tip snaps off. This exposes the upper, pointed part of the hair, which works like a hypodermic needle. The fine, stiff tube pierces the animal's skin, and the base of the hair contracts to push the poison up the hollow hair, through the tip, into the wound.

3 The liquid emerges through the tip of the sting partly as a result of the pressure being released, and partly because the base of the hair pushes the liquid upward. Each hair can only sting once. After stinging its victim, the sting disintegrates and falls off the plant.

Tight grip
If a nettle is gripped very firmly, the hairs are broken off near the base and the tips are unable to pierce the skin.



Stinging nettle hair

Nucleus
The nucleus of the cell exists in a region separated from the vacuole (pp. 8–9).

Vacuole

A large vacuole, which extends from the base to the tip of the stinging hair, is filled with a cocktail of chemicals, including formic acid, histamine, and acetylcholine.

Base of sting

The thin-walled, swollen base of the stinging hair is set into a column of cells. These cells are called epidermal cells. They extend from the surface of the plant.

Spiny coats

Many plants rely for protection on physical defenses instead of poisons. Thistles have sharp spines in the leaves and stem, and the unopened flowers are protected by spiny flaps called bracts while they develop. Any animal trying to eat a thistle will get a painful mouthful of spines.

Bypass

As the poison moves toward the broken tip, it bypasses the nucleus.

Squeezing in

The bottom of the sting squeezes in even more to push poison up to the tip.

Cells

When the tip is broken, pressure inside the hair is released. This allows the cells around the base to contract, squeezing the poison along the hair.

Pressure

These cells exert pressure on the base of the stinging hair.

Cell shape
The epidermal cells are longer and thinner where they are attached to the hair.



Leaf moats

On some plants, such as teasel, water collects where two leaves meet the stem at the same point. These little pools of water act like moats around castles. Snails and insects trying to climb the plant to feed on the young leaves cannot cross the water barrier. They have to turn back, or they fall into the water and drown.

Cell remains

Once the dead hair has fallen off, the epidermal cells remain, like a stump, extending from the plant.



Cacti and succulents

About 10,000 species of flowering plants are succulents. Succulents survive the dry conditions in which they live thanks to efficient roots to gather water and a thick “skin,” or cuticle, to prevent all the water stored inside their swollen leaves, stems, or roots from evaporating. Cacti, a kind of succulent, store water in fleshy green stems. They have spines instead of leaves to minimize water loss and to protect them from plant-eating animals.



Spiny armor

The sharp leaf prickles of this agave plant help stop animals from reaching the water in its leaves.



Stem disguise

Epiphyllum cacti have flat, leafless stems that look like leaves. The stems also work like leaves, making food for the plant. In the wild, these cacti grow on rain forest trees.



Leaf rosettes

Haworthias usually grow in tight rosettes of leaves close to the soil level. This helps trap moisture near the plant. The roots of haworthias can shrink to draw the plant down into the soil.

Green stem

The green stem photosynthesizes since there are no leaves to make food.



Root patterns

The roots of cacti usually spread out widely in a shallow network near the soil surface. This is so that they can catch any rain that may fall. Cactus roots, such as the roots of this golden barrel, can absorb water quickly and can also take in droplets of dew that form on the plant in the early morning.

Growing up

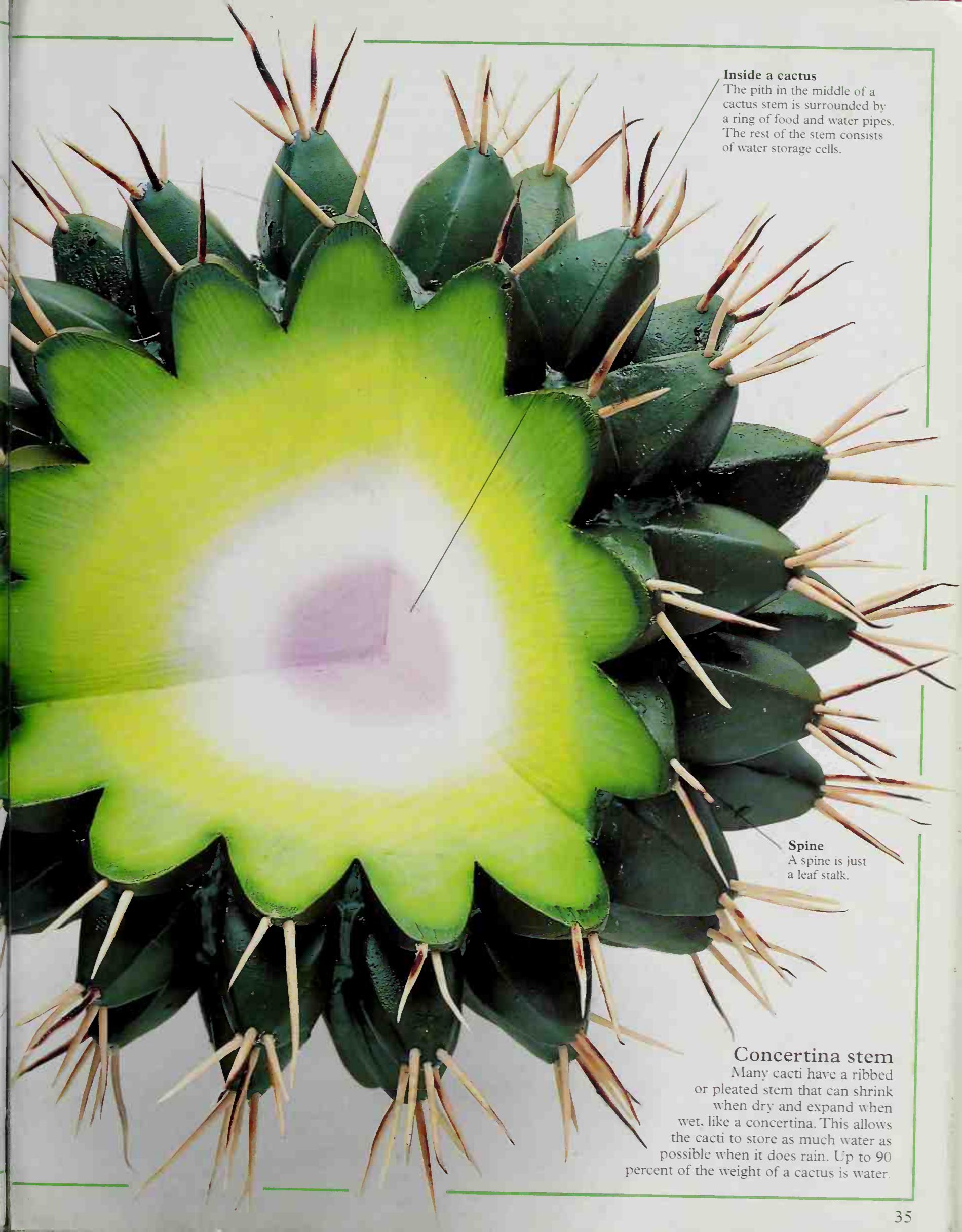
Some roots grow up to the surface, instead of down, to catch surface moisture.

Tough skin

Tough, waxy, waterproof “skin” stops water from escaping into the air.

Inside a cactus

The pith in the middle of a cactus stem is surrounded by a ring of food and water pipes. The rest of the stem consists of water storage cells.



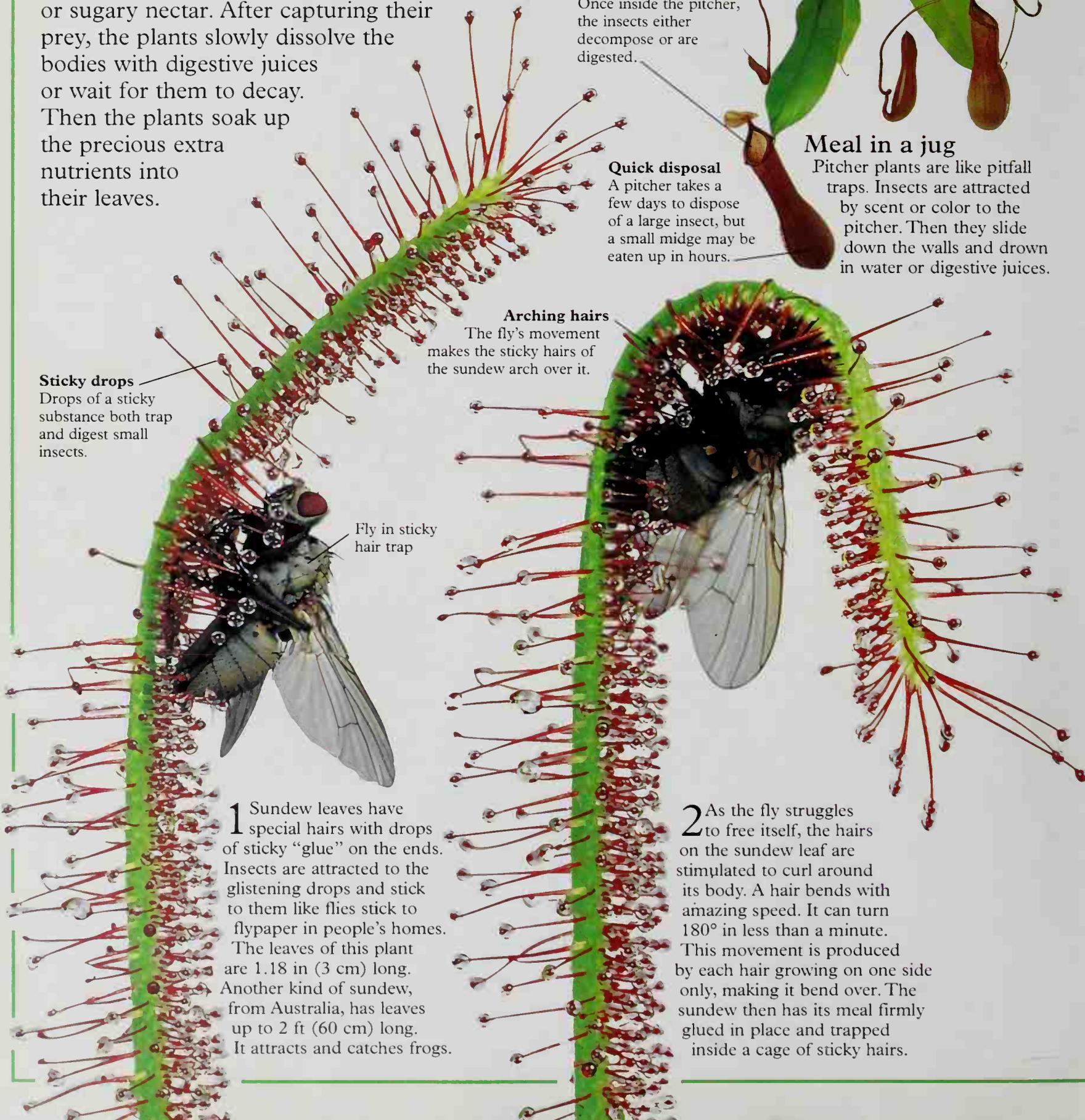
Concertina stem

Many cacti have a ribbed or pleated stem that can shrink when dry and expand when wet, like a concertina. This allows the cacti to store as much water as possible when it does rain. Up to 90 percent of the weight of a cactus is water.



Animal traps

In places with poor soil, some plants gain extra nourishment by trapping insects and other small animals with their leaves. These leaf traps range from water-filled leaves called pitchers to sticky flypaper leaves to "mousetraps" and hinged jaws. The pitcher leaves do not move, but the other leaf traps do. Plants that digest insects and animals are called carnivorous plants. They usually attract their victims with smell, color, or sugary nectar. After capturing their prey, the plants slowly dissolve the bodies with digestive juices or wait for them to decay. Then the plants soak up the precious extra nutrients into their leaves.





Mousetraps

Underwater bladderworts have small sacs on thin, feathery leaves. These sacs have a trapdoor with a trigger hair. The slightest movement of the trigger causes the door to snap open.

Water is sucked into the space, carrying with it any passing creature.

Jaws of death
If an insect lands on the leaf of a Venus's-flytrap and touches more than one hair, or one hair more than once, the two lobes of the leaf snap shut in about one-third of a second. Small insects may crawl out through the spikes on the leaves, but larger insects are doomed. The lobes crush the insect's body and acidic juices dissolve it into a mushy pulp.

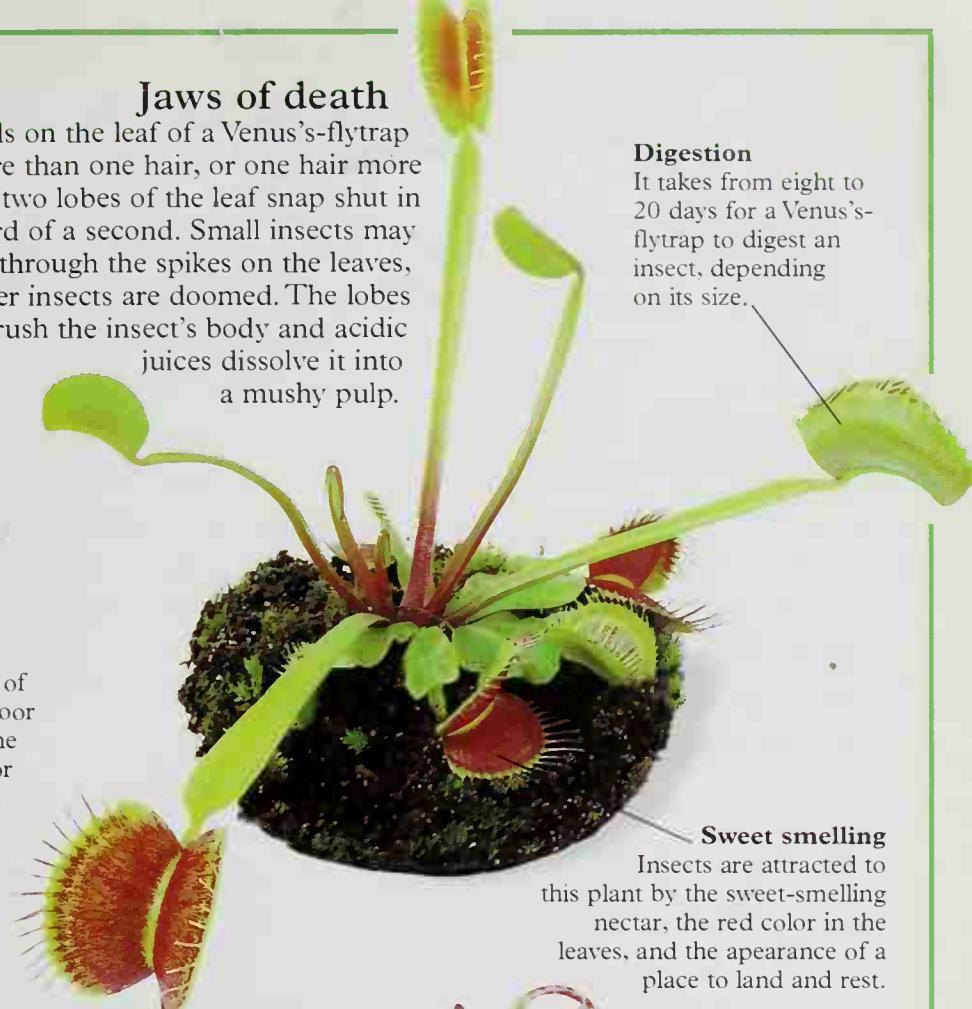
No roots
Bladderworts have no roots. They rely on the nutrients from their efficient traps.

Water pressure

Once the creature is caught, the pressure of the water seals the door and it is digested. The trap is never open for more than a fraction of a second.

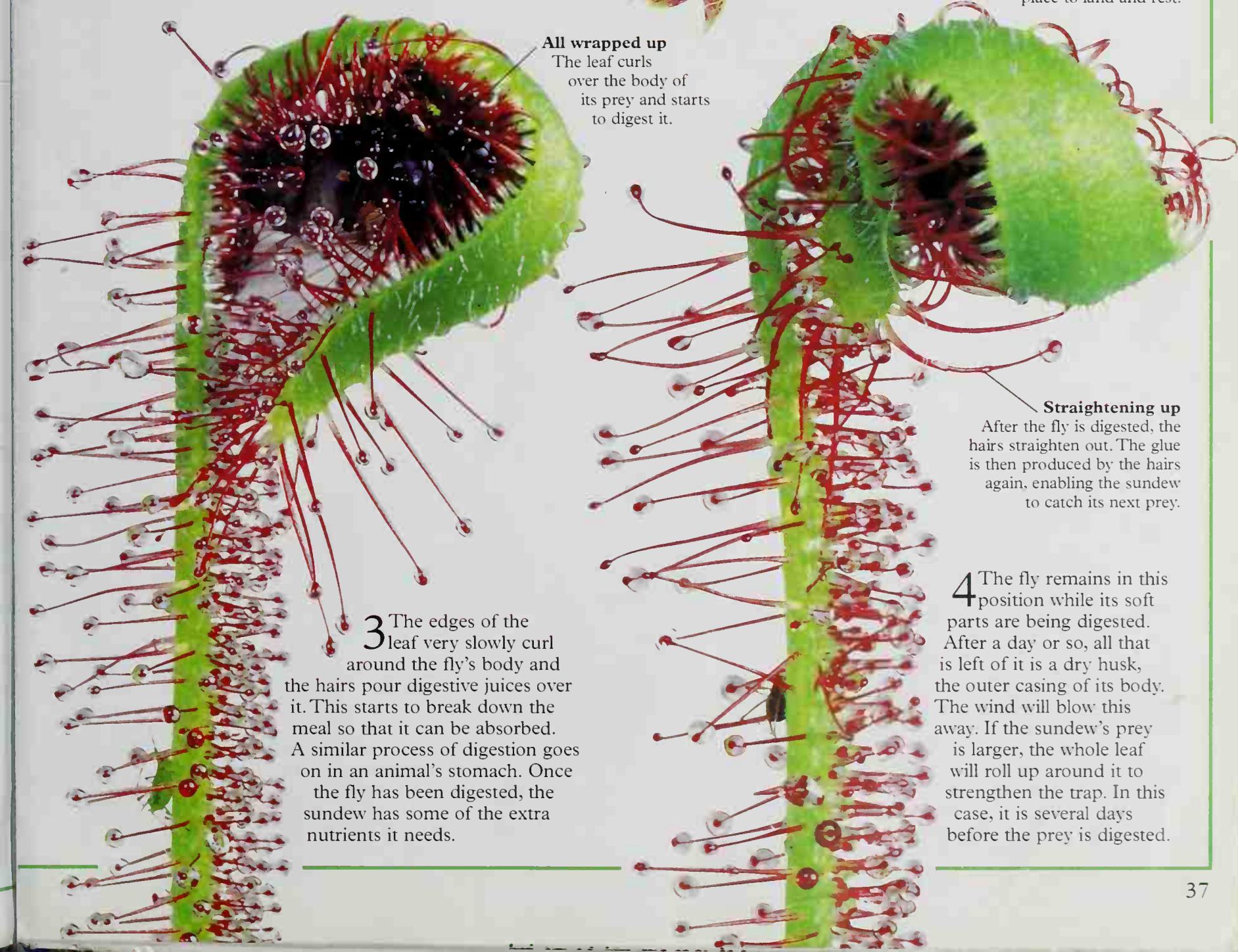
Digestion

It takes from eight to 20 days for a Venus's-flytrap to digest an insect, depending on its size.



Sweet smelling

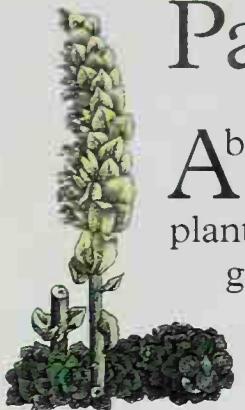
Insects are attracted to this plant by the sweet-smelling nectar, the red color in the leaves, and the appearance of a place to land and rest.



3 The edges of the leaf very slowly curl around the fly's body and the hairs pour digestive juices over it. This starts to break down the meal so that it can be absorbed. A similar process of digestion goes on in an animal's stomach. Once the fly has been digested, the sundew has some of the extra nutrients it needs.

4 The fly remains in this position while its soft parts are being digested. After a day or so, all that is left of it is a dry husk, the outer casing of its body. The wind will blow this away. If the sundew's prey is larger, the whole leaf will roll up around it to strengthen the trap. In this case, it is several days before the prey is digested.

Parasitic plants



About one percent of all flowering plants – several thousand kinds – steal all their food from other plants. They are called parasites, and the plants they grow on are called hosts. Many parasites attach themselves to their hosts by rootlike suckers called haustoria. The haustoria grow into the host's xylem and phloem (pp. 28–29) and suck out nourishment. A few parasites live completely inside their hosts, except when they flower. Some parasites grow on a variety of different hosts, while others grow on only one kind. Half parasites can make their own nourishment, but also depend on their host for some food.

Dodder stems

Threadlike stem of dodder wraps around stem of host plant.

Dependent

Dodder plants are totally dependent on their host plant and cannot live a separate life.

Dodder threads

Threads grow out of the dodder and push their way through the host's cells.

Haustoria

The cells inside the haustoria die off, leaving a hollow "straw" through which the dodder sucks water and food from its host.



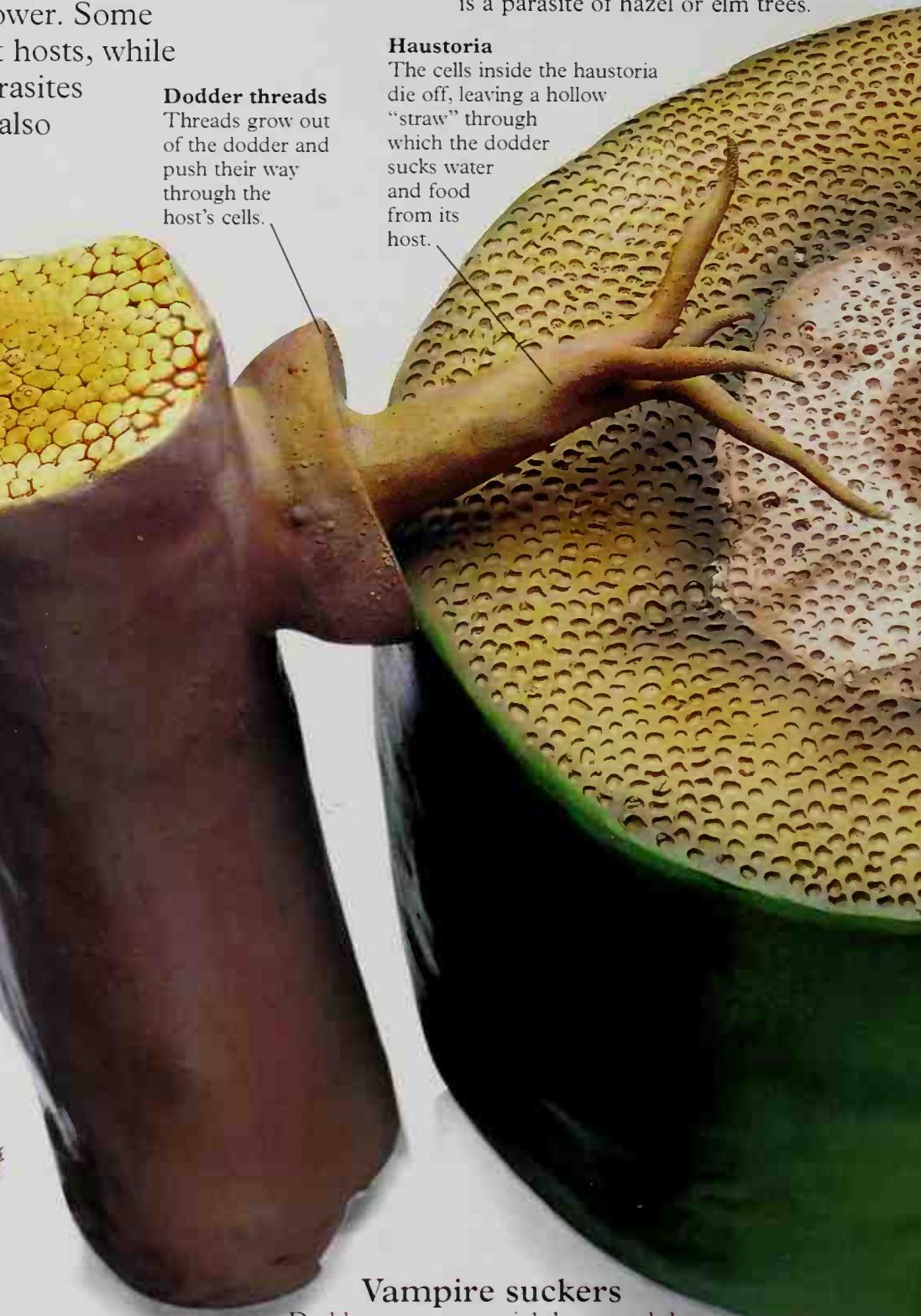
Sickly stems

Parasitic plants such as this toothwort have no green chlorophyll since they do not produce their own food. Toothwort is a parasite of hazel or elm trees.



Suffocating

Dodders produce branching networks of many thin, threadlike stems that can sometimes cover their host completely. Young dodders have roots, but these wither away once the parasite begins to suck food from its host and no longer needs it from the soil.



Vampire suckers

Dodder stems wrap tightly around the host plant's stem. When the two plants touch, the dodder sends out suckers called haustoria at every possible place.

The haustoria push their way into the xylem and phloem and suck out water and nutrients.

Tree passengers

Mistletoe grows on branches of trees from apples and poplars to larches, pines, and firs. The germinating seeds put out haustoria, which worm their way into the tree to seek out the xylem and phloem.



Growing

Once the haustoria reach the xylem and phloem, they grow bigger and develop woody walls.



Dodders are parasitic on a wide variety of plants from alfalfa, ivy, heather, and clover to nettles, hops, and many tropical trees.

Plant spongers

Mistletoe has green leaves to make some food for itself, but it also takes food from its tree host. The sticky berries are often lodged into trees by birds.



Stem

Haustoria are produced only if the dodder stem touches the host's stem.

Spiraling

Dodder stems spiral in the air and are attracted by chemicals given off by the host.

Fusing

Haustoria fuse to the xylem and phloem of the host.



Surprise flower

The biggest flower in the world is produced by the rafflesia parasite, which grows on vines in Borneo and Sumatra. Its flower can be 36 in (91 cm) in diameter. The plant usually lives inside vine roots.

Living together

Some plants develop special partnerships with other living things, from bacteria, algae, and fungi to ants and wasps. In many of these partnerships, the plant has creatures living inside its body, but plants may also live inside animals. The plants and the other living things help each other survive. Ants are particularly common plant partners. They may defend the plant, or provide it with food in return for a safe place to nest.

Healthy leaves

The leaves of the ant plant are healthy. They flourish because the ants have provided the plant with the phosphates and nitrates that it needs.

Perching ivy

Ivy plants climb up trees to get closer to sunlight. They have woody climbing stems that cling to the tree trunks with extra roots called adventitious roots. These grow along the ivy stems to provide extra anchorage. Plants like ivy that live on the surface of other plants without taking water or food from them are called epiphytes.

Plants inside animals

Millions of tiny green plants called algae live inside giant clams. They survive in a space between the clam's soft body and its hard shell and are exposed to the light when the clam opens the two halves of its shell.

The algae feed on some of the clam's waste products while, in return, the clam feeds on some of the algae.

In search of light

This ant plant is an epiphyte, perching on a forest tree to get closer to the light. It cannot take in nutrients from soil.

Leathery leaves

The shoot has leathery leaves and, at certain times of year, small white flowers.

Abscission

A hole, called an abscission, in the stem remains after one of the leaves has fallen off.

Spreading seeds

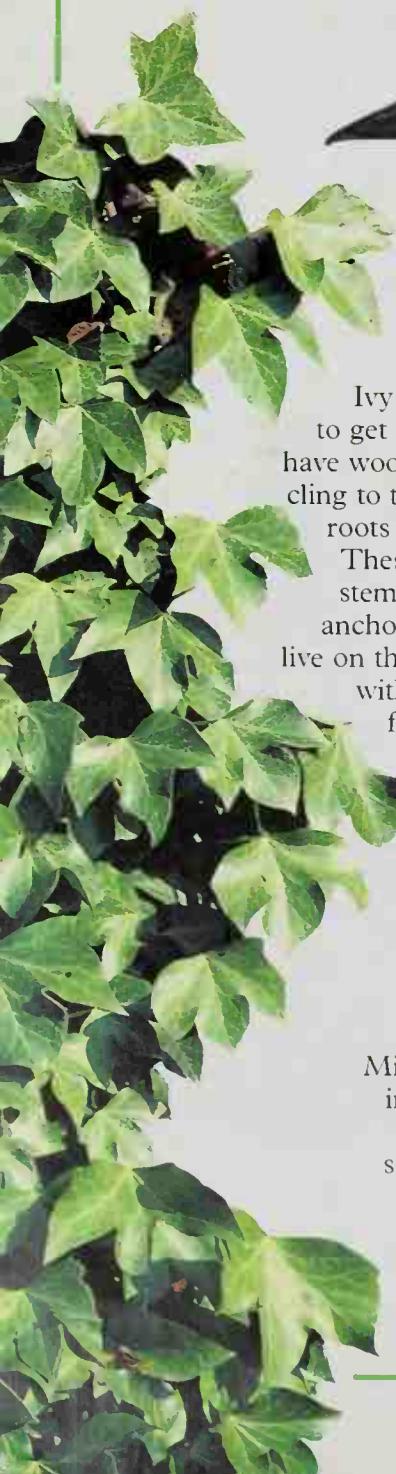
Ants also help spread the seeds of this plant.

Fair exchange

The ants provide the plant with extra food and the plant gives the ants food and a safe home.

Algae

The green patches are groups of algae living inside the clam.





Insect nurseries

When some insects lay their eggs inside plants, it may cause the plants to grow in a strange way and produce galls. The galls provide food for the insect larva that hatches out of the egg. These spiked pea galls have tiny wasps developing inside them.

Chambers

The ant plant forms chambers, whether ants live there or not.

Smooth walls

Chambers with smooth walls are used as living quarters and nurseries.

Tight hold

Short roots hold the plant in place high up on the trunk of a tree.

Warty walls

In chambers with warty walls, the ants place their droppings and the leftovers from their insect meals.



Entrance

Ants enter and leave through holes on the surface of the swollen stem.



Natural fertilizer

Many plants in the pea family, such as clover, have bacteria living in nodules on their roots. The bacteria take in nitrogen from the atmosphere and turn it into a form that the plant can use. This helps the plants survive in soils low in nitrogen.

Ant lodgers

This ant plant has a colony of ants living in chambers inside its swollen stem. Some chambers are used to rear young, while others are the ants' garbage dumps. The garbage contains nutrients that the ant plant absorbs through the walls of the chambers.

Glossary



A

Algae

A varied group of plants, or plant-like organisms, with no roots, stems, or leaves, living in water or in damp places.

Anther

The part of a flower stamen that produces pollen.

C

Cambium

A layer inside roots and shoots that contains cells that keep dividing and growing. It produces xylem from one side and phloem from the other side.

Camouflage

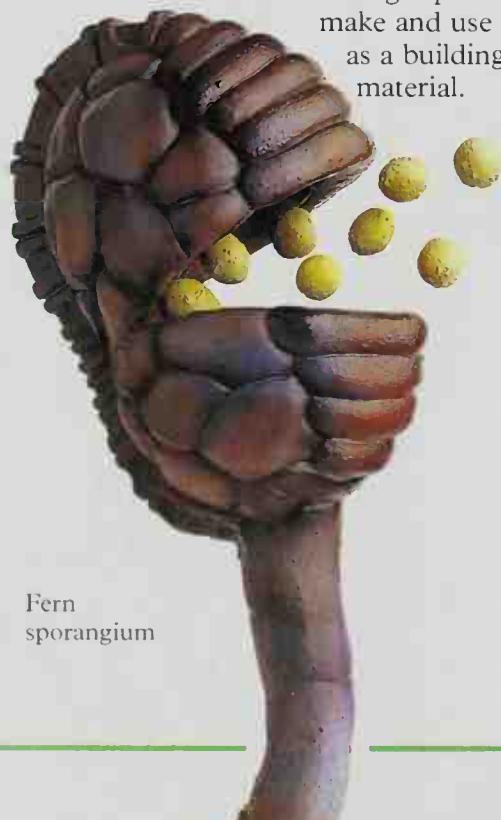
A disguise that helps hide a plant from animals that might eat it. It usually involves colors, patterns, or shapes that blend with the plant's surroundings.

Cell

The smallest living unit. Plants are built of cells with rigid cell walls.

Cellulose

A kind of sugar plants make and use as a building material.



Fern
sporangium

Chlorophyll

A pigment inside chloroplasts that captures light energy for photosynthesis.

Chloroplast

A microscopic sac in most green plant cells in which photosynthesis takes place.

Cotyledon

The first leaf or leaves of a seed plant, found in the seed. Some cotyledons store food and stay below ground when the seed germinates. Others open above ground.

Cytoplasm

The living contents of a cell, except for the nucleus, which are inside the cell membrane.

D

Dicotyledon (Dicot)

A flowering plant with two



Plant cell

cotyledons in its seed. Dicots usually have broad leaves with branching veins in a netlike pattern.

E

Embryo

A young developing plant inside a seed.

Epidermis

The outer layer of cells in stems and leaves.

Epiphyte

A plant that grows on the surface of other plants for support, but does not take water or food from them.

F

Fertilization

The joining together of special male and female cells to make a new living plant. Male cells are in pollen grains and female

egg cells are in ovules.

Filament

Any threadlike structure, such as the stalk of a flowering plant stamen.

Fern sorus



Floret

A small individual flower within a flower head.

Fruit

The ripe ovary of a flower containing seeds. Fruits can be either fleshy and juicy or hard and dry.

G

Gall

An abnormal growth on a plant stem or leaf, that is caused by the activity of insects, fungi, or bacteria.

Germination

The process in which a new plant starts to grow from a seed or a spore.

H

Haustorium

A threadlike outgrowth of the stem, root, or hyphae of parasitic plants or fungi through which they absorb nutrients from the host.

Host

An animal or plant used by another animal or plant as a source of food.

Hyphae

Threadlike strands or filaments making up the body or mycelium of a fungus.

M

Membrane

A thin barrier around a cell controlling the substances that pass in and out.

Meristem

A zone of growth in a plant where cells divide so that the plant grows bigger. The main meristems are at the tip of each root and shoot.

Monocotyledon (Monocot)

A flowering plant with only one cotyledon in its seed. Monocots have parallel veins in their leaves.

Mycelium

The network of hyphae that make up the body of a fungus.

N

Nectar

A sweet liquid produced by flowers and some leaves to attract insects, and some birds, for pollination.

Nucleus

The control center of a cell which contains the genetic information.

Runner bean



O

Ovary

The part of the female reproductive system that contains ovules.

Ovule

The part of the ovary in seed plants that contains the egg cell and develops into the seed after fertilization. There are usually several ovules in an ovary.

P

Parasite

A plant that obtains its food from another species, the host, usually harming the host in some way.

Petal

A modified leaf, often brightly colored, that joins with others to form a ring inside the sepals of a flower. Colored petals help attract animal pollinators.

Phloem

The living food pipes in plants through which sugary sap is carried up and down to all parts of the plant.

Photosynthesis

The process by which green plants use the Sun's energy to turn carbon dioxide gas and water into sugars, plant food.

Pith

A mass of spongy packing cells often found in stems.

Plumule

The developing shoot of a plant embryo, made up of a short stem and young leaves.

Pollen

Fine powder produced by anthers and male cones of seed plants. Each pollen grain contains a male sex cell.

Pollination

The transfer of pollen from the male part of a flower to the female part.

R

Radicle

The first root in a seed, produced by the embryo.

S

Second

A structure consisting of an embryo and a food store, called the endosperm, surrounded by a protective coat called a testa.

Sepal

The leaflike outer parts of a flower that protect the bud.

Sorus

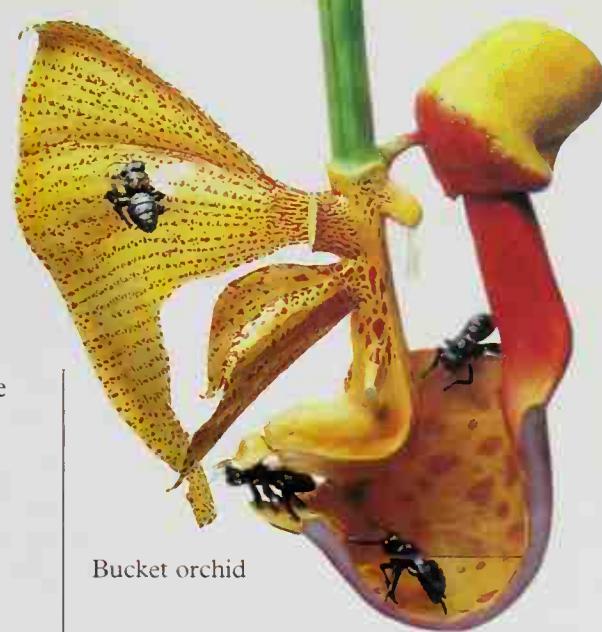
A cluster of sporangia in ferns, fungi, mosses, and algae.

Sporangium

A structure that makes spores in ferns, fungi, mosses, and algae. More than one sporangium are called sporangia.

Spore

A small reproductive structure of a fern, fungus, moss, or alga, which is capable of growing into a new plant. Spores are usually made up of one cell and are not the result of fertilization.



Bucket orchid

Stamen

A structure that makes pollen in a flowering plant. A stamen is made up of a stalk or filament with sacs of pollen called anthers on the end.

Stigma

A structure that receives pollen and is usually connected to the ovary by a stalk called the style.

T

Tuber

A rounded swelling at the end of an underground root or shoot.

X

Xylem

A system of water pipes in plants made up of rows of dead cells joined end to end. Xylem carries water and minerals upwards, from roots to leaves.

Pine stem



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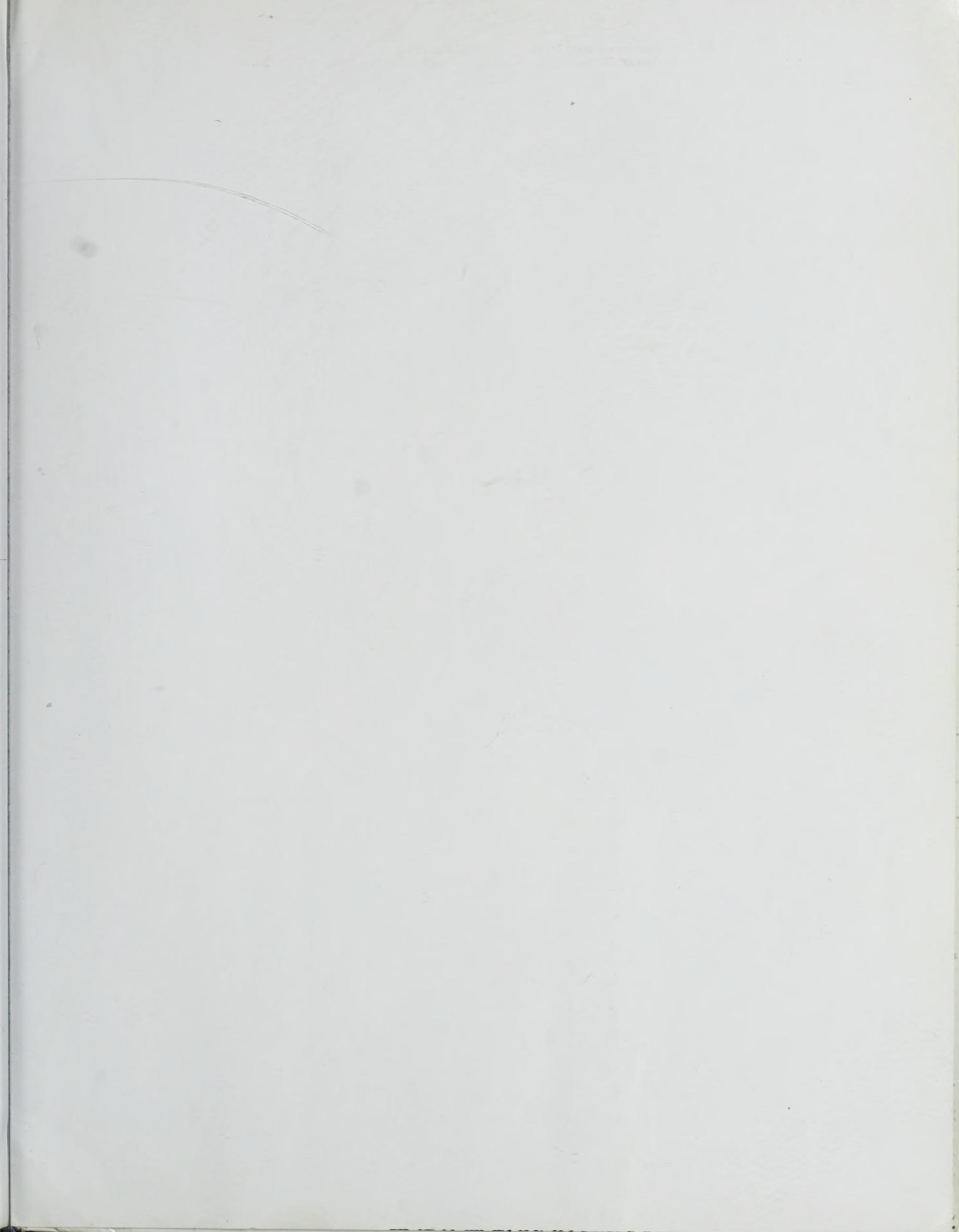
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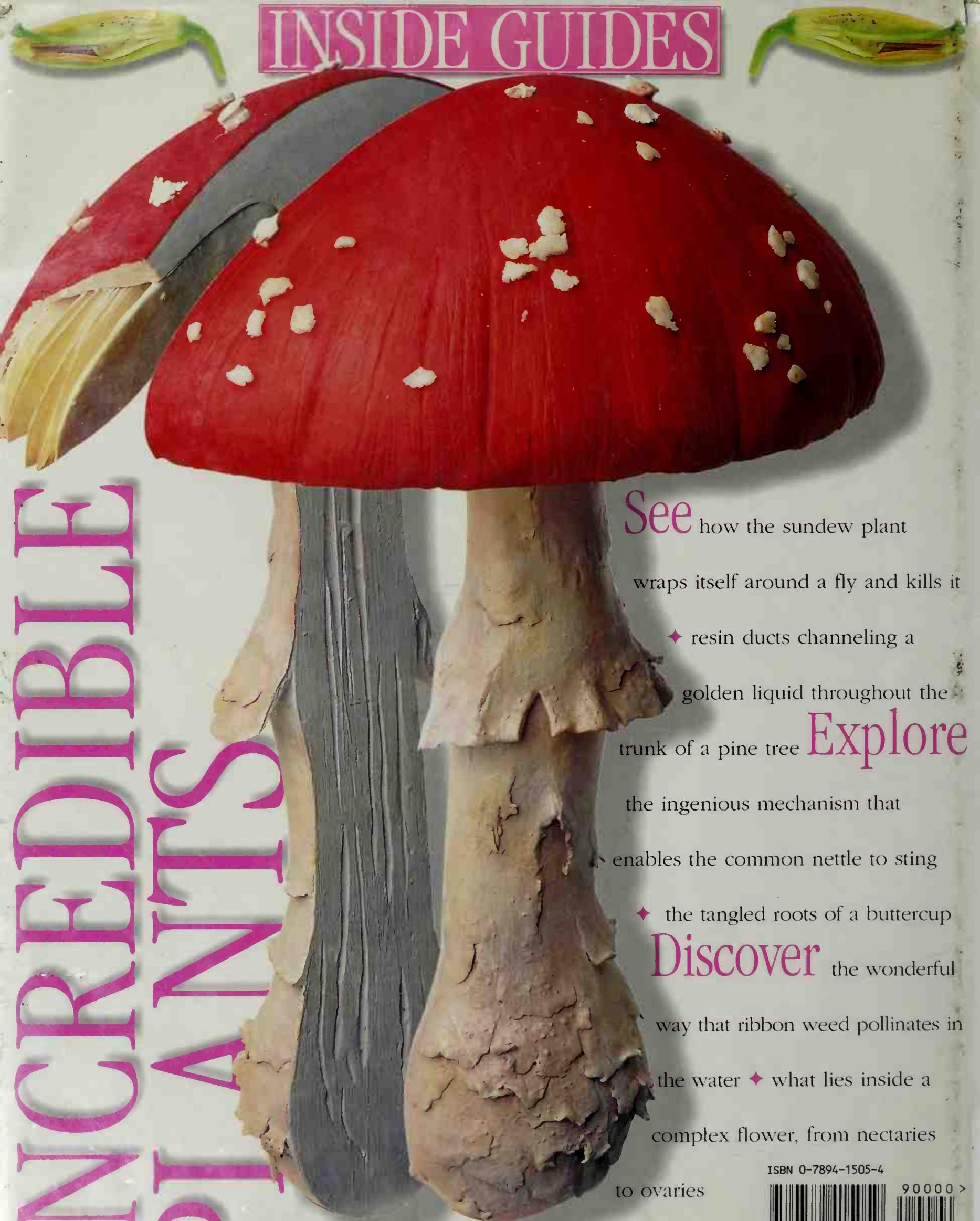
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